DEFENSE AIRBORNE RECONNAISSANCE OFFICE

AIRBORNE RECONNAISSANCE ARCHITECTURE

VERSION 0.8

FEBRUARY 1998

EXECUTIVE OVERVIEW

Cleared for open publication April 27, 1998

Comments/Questions

OUSD(A&T)/DARO
Attn: Mr. Kenneth Lindsey
Director, Architecture & Integration
3160 Defense Pentagon
Washington, DC 20301-3160

e-mail (Unclassified Only): lindsek@acq.osd.mil

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1998	Draft Initial Report Version 0.8

4. TITLE AND SUBTITLE
The Defense Airborne Reconnaissance Office (DARO) Airborne Reconnaissance Architecture (ARA) Executive Overview

5. FUNDING NUMBERS
N/A

6. AUTHOR(S)
Defense Airborne Reconnaissance Office

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Defense Airborne Reconnaissance Office
OUSD(A&T)/DARO
3160 Defense Pentagon Suite 4C1045
Washington, DC 20301-3160

8. PERFORMING ORGANIZATION REPORT NUMBER
ARA EO Version 0.8

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Defense Airborne Reconnaissance Office
OUSD(A&T)/DARO
3160 Defense Pentagon Suite 4C1045
Washington, DC 20301-3160

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
ARA EO Version 0.8

11. SUPPLEMENTARY NOTES
Executive Summary of Draft DARO ARA Version 0.8

12a. DISTRIBUTION AVAILABILITY STATEMENT
DISTRIBUTION A: Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE
PB

13. ABSTRACT *(Maximum 200 words)*
This is the Executive Overview of the DARO Airborne Reconnaissance Architecture (ARA) Version 0.8. The DARO ARA is an in-progress report of the on-going architecture development work of the Defense Airborne Reconnaissance Office (DARO) as required by DoD Directive 5134.11.E.1. This document provides an overview of the ARA which reflects the development of a framework for designing an intelligence, surveillance and reconnaissance (ISR) architecture that is responsive to the revolutionary directions presented in joint and service-specific vision documents for the timeframe 2010 and beyond.

14. SUBJECT TERMS
DARO; DARO ARA; C4ISR Architecture; Executive Overview

15. NUMBER OF PAGES
44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

PREFACE

The Defense Airborne Reconnaissance Office (DARO) was established in November 1993 by the Deputy Secretary of Defense to be the primary office within the Department of Defense (DoD) responsible for improving joint-service and defense-wide manned and unmanned aerial reconnaissance capabilities, including sensors, data links, data relays, and ground stations. Under DoD Directive 5134.11, dated April 5, 1995, a primary responsibility of the DARO is to "develop and maintain the DoD integrated airborne reconnaissance architecture for the development, demonstration and acquisition of improved airborne reconnaissance capabilities and provide associated oversight to ensure compliance." (DODD 5134.11.E.1.)

The Defense Airborne Reconnaissance Steering Committee, co-chaired by the Under Secretary of Defense (Acquisition and Technology) and the Vice-Chairman, Joint Chiefs of Staff, established the scope of the DARO's architecture responsibilities at its first meeting (March 1994) to encompass the systems assigned to the Defense Airborne Reconnaissance Program (DARP) plus, for architecture purposes, selected non-DARP systems as shown below.

DARP	NON-DARP
U-2R/S	E-8C JSTARS
RC-135V/W RIVET JOINT	RC-7 Airborne Reconnaissance-Low (ARL)
RQ-4A Global Hawk ACTD	RC-12 GUARDRAIL
RQ-3A DarkStar ACTD	Aerial Common Sensor (ACS)*
EP-3E ARIES II	RC-135S COBRA BALL
REEF POINT	C-130 PACER COIN
RC-135U COMBAT SENT	C-130 SENIOR SCOUT
RQ-1A Predator	ES-3A SHADOW
RQ-2A Pioneer	F-14 TARPS
Outrider TUAV ACTD*	F/A-18D (ATARS)
Tactical Control System*	F/A-18F (RECCE)
Distributed Common Ground System	F-16 TARS
SR-71*	

* indicates systems assigned to the DARP after DARSC 1
(ACTD = Advanced Concept Technology Demonstration)

DARO ARCHITECTURE DEVELOPMENT TEAM

The DARO established the DARO Architecture Development Team (DADT) to provide the integrated airborne reconnaissance architecture description required by DODD 5134.11.E.1. To this end, the DADT developed a framework for designing an intelligence, surveillance, and reconnaissance (ISR) architecture that is responsive to the revolutionary directions presented in joint and service-specific vision documents for the timeframe 2010 and beyond. The resulting *vision architecture* is a network-centric, internet-like, global ISR enterprise that can concurrently serve warfighters at all echelons, as well as intelligence producers. The DADT also sized a *force mix* of ISR platforms, sensors, ground/surface stations, and associated collection communications

to satisfy warfighter needs in the 2010 timeframe. The proposed force mix is consistent with the National Military Strategy for supporting two major theater wars (MTWs), including assets to support sensitive reconnaissance operations, training, test, and logistics. A *distributed reconnaissance infrastructure* comprising the system functions of collection management, processing, exploitation, and dissemination has also been described. The proposed force mix is supported with modeling and simulation performance analyses, a viable migration path, and life-cycle cost estimates. This report documents the architecture development work of the DARO's DADT.

DADT COMPOSITION

The composition of the DADT is shown below. This collection of individuals brings together extensive experience with airborne ISR, with DARO, and with sophisticated analytic processes suited to architecture development.

Name	Principal Focus
Col Mike Francis	DADT Study Leader; Director A&I Division (to Oct 97)
Ken Lindsey	Director, A&I Division
Frank Cook	DADT Study Executive Director, Architecture Analysis
Hank Barrows	Orbits/Tracks Analysis, Partnership Studies Integration
Paul Belmont	DARP Budget and Migration Path Analysis
Pat Branch	Mission Planning, Intelligence Production
Roger Burk	Performance Optimization Modeling, Simulation, and Analysis
Dave Craig	Imagery Intelligence Architecture Concepts Evaluation
Steve Dam	Modeling, Functional Decomposition Analysis
Rick Deason	Legacy Systems Analysis/Operations
Ralph Holm	Force Mix Analysis/Acquisition
Kirk Hoy	Life-Cycle Cost Evaluation
John Koss	Technology Insertion & Measurement and Signature Intelligence
Gif Munger	Unmanned Aerial Vehicle Modeling/Tactical Sensor Operations
Ken Myers	Modeling & Simulation Evaluation
Warren Ono	Cost Models/Data Support
Susan Parker	Production, Exploitation, Dissemination Systems, and Analysis
Leo Seale	Integrated Road Map/Administrative Support
Ken Stanford	Operations Signal Intelligence Evaluation
Rick Storer	Operational Military Worth M&S Analysis
Maj Ted Warnock	Modeling, Simulation, and Analysis Team Leader, Air Force Studies and Analyses Agency

The DADT operated from the National Reconnaissance Office's Westfields Headquarters facility in Chantilly, Virginia. This location provides opportunity for interaction and joint analyses with the NRO's Programs and Analysis Division, which is engaged in extensive modeling and analysis of the performance of overhead ISR assets. Another source of dynamic interaction is DARO's Advanced Development Division, which is also located at Westfields and oversees the DARP Technology Development Program, so vital to the future viability of airborne platform and sensor capability.

The DADT was assisted in identifying technology opportunities to meet the projected needs of the vision architecture by the DARO's Advanced Technology Division and by a distinguished panel of technical advisors chaired by Dr. Gene H. McCall. Members of this panel include:

Dr. Gene H. McCall, Chairman	Los Alamos National Laboratory	Technology Development, New World Vistas
Dr. Stewart D. Personick	Bellcore	Emerging Telecommunications Networks
Dr. Peter R. Worch	Consultant	Systems Architecture
Dr. Robert D. Turner	Institute for Defense Analysis	Command and Control Analysis
Dr. Jack I. Walker	ERIM International	Sensors
Dr. Walter B. LaBerge	Institute for Advanced Technology	Strategic Assessments
Mr. Carl H. Builder	Rand Corporation	Future World States
Dr. Joseph Polito	Sandia National Laboratory	Modeling and Simulation
Dr. Paul J. Berenson	Army Training and Doctrine Command	Technology Applications
Dr. Robert E. Conley	Conley and Associates	Information Systems
Dr. Bruce Wald	Arlington Education Consultants	Communication Systems

Advice on operational issues relevant to the vision architecture was provided by members of DARO's Senior Review Group. Those assisting the DADT in periodic reviews of progress, direction, and conclusions included:

MajGen John Corder, USAF (Ret)

MajGen Eric Nelson, USAF (Ret)

RADM Riley Mixon, USN (Ret)

Mr. Robert Nesbit (MITRE)

Finally, the DADT also established partnership alliances with other organizations conducting analyses contributing to our collective understanding of airborne and space reconnaissance. Major contributors among these partners include:

Air Force Studies and Analyses Agency

- Col Roger Geer
- LtCol Mike McGinty
- Maj Ted Warnock
- Maj Jim Barnes

National Reconnaissance Office

- Lt Col Randy Chapman
- Tanya Pemberton
- Capt Bruce Chesely

Defense Intelligence Agency

- Laurie Kelly
- Jim Watson

National Imagery and Mapping Agency

- Dusty Rhoades

National Security Agency

- Maj Phil Sauer

Joint Staff

- Lt Col Lee Allen

Army Office of Deputy Chief of Staff for Intelligence

- Rob Zitz

0. EXECUTIVE SUMMARY

This document is an in-progress report of the on-going architecture development work of the Defense Airborne Reconnaissance Office (DARO).

0.1 INTRODUCTION

DARO was established in November 1993 to be the focal point within the Department of Defense (DoD) for the improvement of joint service and defense-wide aerial reconnaissance capabilities. This responsibility includes manned and unmanned systems, as well as sensors, datalinks, data relays, and associated ground stations. DoD Directive 5134.11 assigned to DARO the responsibilities for developing and maintaining "the DoD integrated airborne reconnaissance architecture" and for "the development, demonstration, and acquisition of improved airborne reconnaissance capabilities." The DARO established a multidisciplinary team of experts known as the DADT (DARO Architecture Development Team) to develop and describe the integrated airborne reconnaissance architecture.

The purposes of this report are to describe the proposed architecture and to explain the process being used by the DADT to develop the architecture. These purposes are accomplished in the following way. First, this executive summary highlights the major considerations that underlie the architecture development process and the major features of the proposed architecture. Second, the remaining sections furnish more detailed accounts of the vision behind the architecture (see Section 1), the architecture itself (see Section 2), the migration path to the architecture (see Section 3), the performance characteristics of the architecture (see Section 4), and the life-cycle cost of the architecture (see Section 5). The final section considers ways to demonstrate the architecture in a *virtual proving ground*, an approach that combines real-word implementation and virtual-world simulation (see Section 6).

0.2 SUMMARY

This subsection includes a summary of the major considerations that went into the development of the architecture and a summary of the major features of the proposed architecture.

0.2.1 Major Considerations

The development process began with guidance that flowed principally from joint and individual service views of how future military operations will be conducted and from the National Military Strategy, which requires support of two major theaters of war (MTW). The operational concepts defined in *Joint Vision 2010* include dominant maneuver, precision engagement, focused logistics and full dimensional protection. Information superiority is essential for these kinds of operations. The high tempo of these operations will shorten the time available to obtain information; successful maneuver, engagement, and protection will require that our forces be continuously aware of the changing situations of enemy forces; and precision weaponry requires precise targeting information. In addition, future concepts will demand that much information be made available directly to the warfighters, but in ways that avoid information overload.

Fortunately, the revolution in information technologies and advances in other technologies (e.g., sensors) make possible the achievement of these visionary operational concepts. Vastly improved communications and digital networks, using very fast transmissions and large bandwidths, could become the links between various battlefields and headquarters throughout the world. A significantly advanced version of today's internet could support a land, air, and space global grid capable of providing near instantaneous information to warfighters and decisionmakers in any conflict environment. Figure 0-1 illustrates the global networking that is possible.

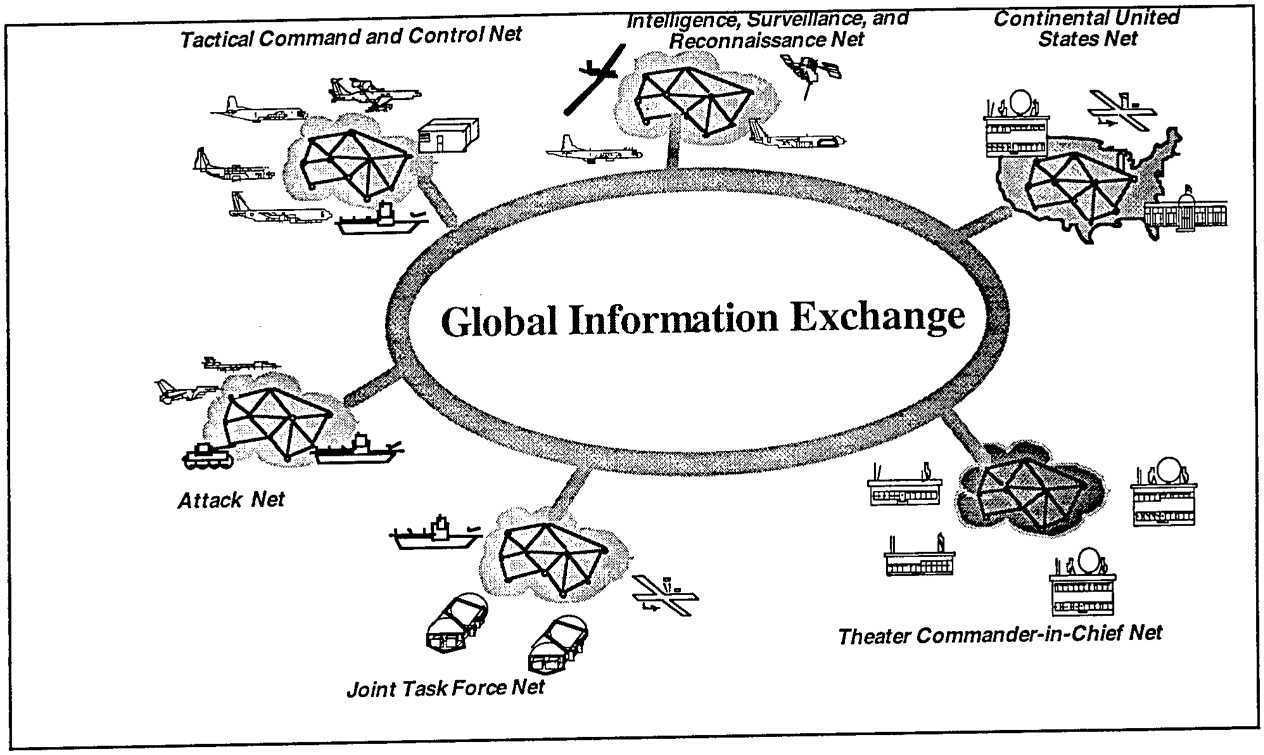

Figure 0-1. Future Global Networking

However, there is a stark contrast between the fast-paced advances that can be projected in information and sensor technologies and the longer time lines associated with implementing changes in airborne reconnaissance platforms. The many platforms that exist today are the "elevators" that lift sensor payloads into view of targets or other observables. The simplicity of this analogy belies the tremendous expense of the platforms as a fraction of the overall cost of the architecture. Current projections are that, in the future, resources to operate existing platforms and to acquire new platforms will be very limited. Accordingly, a central theme of this report is that platforms operating in the same place with the same general operating characteristics are logical choices for consolidation onto one type of platform. Opportunities for joint application of platforms, across separate missions and among separate services, were identified and examined as part of the process of developing the architecture.

In analyzing the performance of candidate architectures, one of the most difficult issues is determining their military worth. The analyses that supported development of the proposed architecture reflected the need to evolve from the traditional intelligence-centric view of military worth, which extends only from receipt of tasking to the delivery of data, to a much broader view that addresses the *value of battlefield information.* This broader view best informs decisionmakers and operators about the merits of one architecture over another (e.g., by indicating whether a campaign is shortened by some number of days because of the choice of an architecture). As part of this architectural development process, new approaches were established to bring greater rigor to the assessment of the true military worth of airborne intelligence assets. In addition, the results of analyses by other groups were taken into account. Although there is room for improving the analytical tools, important insights were revealed during this study. These include the following:

- The communication and exploitation of information are the major factors supporting the operational concepts of *Joint Vision 2010*; adding to today's impressive ability to collect information is of next importance.
- Intelligence collection and production sources must be internetted to support assured information delivery and to avoid unreasonable consumption of resources by the continued use of single-purpose ("stovepiped") systems.
- Satellites and aircraft fill different needs, but they are complementary; their use in combination provides the greatest overall benefit to achieving information superiority.

Another difficult analytical issue concerns the cost of candidate architectures. New ground was plowed during this study in order to estimate, accurately, all of the elements that make up the total life-cycle cost of an architecture that can support two nearly simultaneous MTWs. In addition to the front-end acquisition costs (i.e., research, development, test, evaluation, and procurement), the operations and maintenance costs and military construction assets associated with various architectures are important contributors to life-cycle costs. Over the 14-year time span from 1997 to 2010, the costs of sustaining the existing baseline fleet of airborne platforms and sensors are significant, given its relatively high operational tempo, manpower intensive structure, and continuing modification programs. Attrition costs (i.e., for replacement of air vehicles lost or destroyed during peacetime operations) are also substantial.

0.2.2 Major Features of the Vision Architecture

Consideration of projected operational needs (especially the requirement to support two major theaters of war), the availability of advanced information systems, the necessity of consolidating the plethora of current platforms, enhanced measures of the military worth of intelligence assets, and comprehensive estimates of the life-cycle costs of various architectures led to a proposed architecture for the year 2010. There are two distinct segments of this *vision architecture*: (1) a *distributed reconnaissance infrastructure* consisting of augmented communications and other processing, exploitation, and dissemination systems; and (2) a *proposed force mix* consisting of platforms, sensors, and related ground/surface systems.

Among its important attributes, the distributed reconnaissance infrastructure exhibits an internet-like concept of operations that delivers information in real time to warfighters at all echelons of command. The internet feature relies greatly on commercial products and services, and the maturation of internet-like capabilities was assumed to meet the demand for growth in bandwidth and access points. With respect to the communications links, the concepts embodied in the National Space Communications Program and other airborne communications programs now being developed were assumed to be available in 2010.

There are numerous force mix options — combinations of platforms, sensors, and related data links, data relays, and ground/surface control systems — that can satisfy the performance objectives of the vision architecture. The DADT analyzed a number of viable alternative force mix options in great depth with varying assumptions about the outcomes of technology demonstration efforts and life cycle cost projections for sustaining aging current assets. The characteristics of the force mix options that will best achieve the objectives of the vision architecture are described below.

- Platforms are characterized by fewer types than are currently fielded and eventual migration toward dominance by unmanned aerial vehicles (UAVs) because of the projected advantages of UAVs over comparable manned systems.

- Missions now performed by a diverse collection of large systems (e.g. Cobra Ball, Combat Sent, EP-3E AIRES II, RC-135 Rivet Joint, and Joint Surveillance and Target Attack Radar System (JSTARS)) could be consolidated on a few new, common aircraft types.

- Numerous signals intelligence analysts on board today's large manned platforms (the EP-3E and RC-135) could be moved to operate on the ground as part of a migration to remote analysis.

- Four separate tactical reconnaissance pod programs (e.g., F-16 and F/A-18 variants) should be unified with common sensors into a single pod or family of closely related pods carried by the Joint Strike Fighter.

- Advanced versions of the high altitude endurance UAVs, modeled after the Global Hawk and DarkStar advanced concept technology demonstrations, should be developed.

Table 0-1 depicts one viable force mix option for 2010. This particular projection is illustrative of a force mix in which high altitude endurance UAVs replace manned reconnaissance platforms. Several changes in medium-altitude platforms could occur also (e.g., the RC-135 V/Ws could be reduced from the current 16 platforms while still maintaining a 2 MTW capability), and tactical UAVs and improved dual-role fighter reconnaissance capabilities are added in the low-to-medium altitude regime. Any of the force mix projections at 2010 is simply a snapshot in time along the migration path to the longer-term implementation for the vision architecture. Each snapshot represents an intermediate point between the platforms and sensors that exist today and the force that is needed beyond 2010 to support two nearly simultaneous MTWs. The year-by-year evolution of the UAV-dominant force mix alternative is presented in Section 5.

Table 0-2 depicts the 14-year life-cycle costs of this projected 2 MTW force mix in then-year dollars. These costs include the year-by-year costs as the current force migrates to the snapshot in 2010. The single-year costs in 1997 and 2010 are shown, along with the cumulative totals, to portray the reduction in costs for manned systems as compared to the increase in costs for unmanned systems. The total estimated life-cycle cost is approximately $57 billion in then-year dollars.

The life-cycle cost for the distributed reconnaissance infrastructure was not estimated by the DADT. By analogy with the growth of today's internet services, the assumption was that various providers would seek methods of low cost of entry to meeting customer requirements (e.g., migration into something like the subscription services of today's internet industries). Because of the importance of communications to the success of the architecture, continuation of communications-related advanced development and reconnaissance infrastructure projects and programs is assumed. Additionally, it is imperative that support be continued for the Department's communications research and development programs that will eventually deliver the advanced communications environment necessary to enable the information superiority for military operations in the 2010 timeframe to be supported.

An assessment of the affordability of the force mix segment of the vision architecture was explored by comparing extrapolated 14-year DoD budgets for airborne reconnaissance with the life-cycle cost estimates discussed above. While future costs of acquiring and operating systems can be estimated with reasonable accuracy using well developed costing techniques, the same

Table 0-1. Illustrative 2 MTW UAV-Dominant Force Mix Option for 2010

Altitude Regime and Platform Types	Number of Platforms
High Altitude	
Multi-purpose HAE UAV (or Single-purpose)	21 (or 35)
HAE ACN UAV	12
RQ-3A DarkStar UAV	14
Medium Altitude	
E-8C JSTARS	16
RC-135V/W RIVET JOINT	12
RC-135S COBRA BALL/RC-135U COMBAT SENT	3/2
EP-3E ARIES II	11
C-130J(R)	10
ES-3A SHADOW	16
RC-7 Airborne Reconnaissance Low (ARL)	8
RC-12 GUARDRAIL	24
Airborne Common Sensor	12
RQ-1A Predator UAV	48
Medium to Low Altitude	
Tactical UAV	276
F-16/Joint Strike Fighter	20
F/A-18D (Marines)	31
F/A-18F (Navy)	50

ACN = airborne communications node
HAE = high altitude endurance

Table 0-2. Life-Cycle Cost of a 2 MTW UAV-Dominant Force Mix Option for 2010

	Billions of Then-Year Dollars		
	1997	**2010**	**Total (1997 through 2010)**
Manned Systems	2.6	2.2	35
Unmanned Systems	0.5	1.4	13
Other[1]	0.5	0.8	9
Total	3.6	4.4	57

[1] Includes DARO costs for advanced development, reconnaissance infrastructure, and integration and support.

cannot be said about future projections of budgets that might be allocated for airborne reconnaissance. For this analysis, the extrapolated budget value is a conservative inflation-only adjustment to current approved and identifiable funding levels for airborne reconnaissance. Since the force mix projected by the DADT for 2010 supports two MTW (but the budget projection does not), definitive affordability assessment was not practical. The $57 billion cost estimate is approximately $10-to-$16 billion higher than the extrapolated budget estimate over the same period, due in part to certain approved and programmed funding for airborne reconnaissance that could not be identified for inclusion in the baseline for the extrapolation. Analysis of several force mix excursions provided insight into reducing the estimated life-cycle costs for the 2010 architecture.

0.3 CLOSING OBSERVATIONS

The DADT has made several significant contributions to enhancing the understanding of the complex issues posed by the DARO's charter to develop and maintain the DoD airborne reconnaissance architecture. The visionary, internet-like global enterprise that can serve warfighters and intelligence producers alike was discussed above, as were the platforms and sensors to satisfy operational needs in the 2010 time period and beyond. Finally, the DADT developed enlightened approaches to performance and life-cycle cost analyses and responded to the challenge to demonstrate the visionary architecture in a novel way by using a virtual proving ground approach. All of these contributions are described in detail in the body of the report and the appendices.

1. VISION AND OVERVIEW

This section contains a summary of the vision and approach that led to the proposed architecture. The architecture is then described, followed by an overview of the supporting details, which are amplified in later sections.

1.1 APPROACH

1.1.1 A Look Into The Future

Energized by technologies created in the global commercial markets, the national security communities of the United States and its coalition partners are migrating toward widespread internetting of their information infrastructure. This migration forecasts an open but secure systems connectivity in which Department of Defense (DoD) and intelligence networks will be embedded in a land-air-space global grid that will support defense and commercial interests concurrently. A significantly advanced version of today's Internet, this "cybertecture" is fueled by a robust digital communications capability and an intelligent electronic systems backbone to provide near instantaneous answers to critical warfighter issues in any conflict environment.

Shifts in fundamental paradigms are already evident in the move to a political, military, and commercial world where the "fast eats the slow." Large, ponderous information delivery systems and "stovepiped" processes will not work in this world. They must give way to fast, agile systems more ideally suited to support the joint and combined operations of the future. Intelligence, surveillance, and reconnaissance (ISR) architecture descriptions will shift from emphasis on platform and collection systems, which are now well understood, to emphasis on information workgroup support, connectivity, and functionality. Image analysts can be expected to behave much like workgroups do now in emerging commercial and political global enterprises. The current practice of pushing expensive computer hardware onto the warfighter end user will be balanced by a drive to push intelligence onto distributed network servers. As the client-server infrastructure provides a growing share of information transparently to the warfighter, conflict resolution will shift closer to what is now called "network-centric" warfare. This means warfare in which a network rather than a command and control center is the means of receiving, integrating, and disseminating information relevant to the battlespace.

In this world, the reconnaissance infrastructure of 2010 will have the look and feel that is currently recognized as resident in the fast, efficient, responsive, and cost effective global enterprises emerging today. In 2010, the ISR information workgroup *will be* the architecture; the network *will be* the information system; and the laptop or desktop computer *will be* the application gateway.

The Defense Airborne Reconnaissance Office (DARO) Architecture Development Team (DADT) applied this global view to the entire ISR enterprise that will support the U.S. National Military Strategy and the new operating concepts envisioned for the 2010 timeframe and beyond. Some of the most important elements of the strategy and the military operational concepts for 2010 are summarized below.

- **Two Major Theaters of War.** As directed by the Executive Department, and as stated by the Chairman of the Joint Chiefs of Staff in the September 1997 National Military Strategy of the United States; the U.S. military —

"...must be able to defeat adversaries in two distant, overlapping major theater wars from a posture of global engagement and in the threat of WMD [weapons of mass destruction] and other asymmetric threats."

The DADT was asked by the Director, DARO, to follow this guidance in developing the architecture.

- **Respond to the Entire Spectrum of War.** The National Military Strategy also directs the military to:

  *"**Shape** the global environment, **Respond** to the full spectrum of crises, while we also **Prepare Now** for an uncertain future."*

- **Joint Vision 2010.** The joint operational concepts defined for the 2010 timeframe involve dominant maneuver, precision engagement, full dimensional protection, and focused logistics. Information superiority enables these concepts. These and related concepts in the vision documents of the individual services lead to needs such as high-tempo operations, an emphasis on basing in the continental United States, enhanced situational awareness, immediate assessment of battle damage, greater support for precision weapons, and just-in-time logistics.

The DADT recognized that these elements of strategy and military needs can be supported by revolutionary information system technologies that are emerging. These technologies can enable future operations from widely dispersed locations while dramatically improving awareness of the situations of both enemy and friendly forces. Some of the most important technological advances include the following:

- improved digital processors and storage devices
- expanding global communications with wide band satellite networks and an extensive terrestrial fiber grid
- flexible software (e.g., object oriented, platform independent)
- enhanced human-machine interfaces
- better data visualization and three-dimensional display
- more capable sensors and sensing techniques

1.1.2 Architecture Development

In light of the strategy, operational needs, and emerging technologies, an approach for understanding the demands that will be placed on the global ISR system — and hence on the system's architecture — began to take shape. The common theme is that the United States will exact advantage by outstripping the operations tempo of all adversaries. This will force unprecedented demands on the timelines of information that can only be met by revolutionary changes in the way ISR information is processed, exploited and disseminated. This theme must be

superimposed on the already considerable collection capabilities present in the platforms allocated to ISR missions. The overall approach, consisting of information analysis, opportunities analysis, and analyses of operations, performance, systems, and costs, led to the vision for the architecture and the investment strategy to realize the vision. This approach is presented in Figure 1-1.

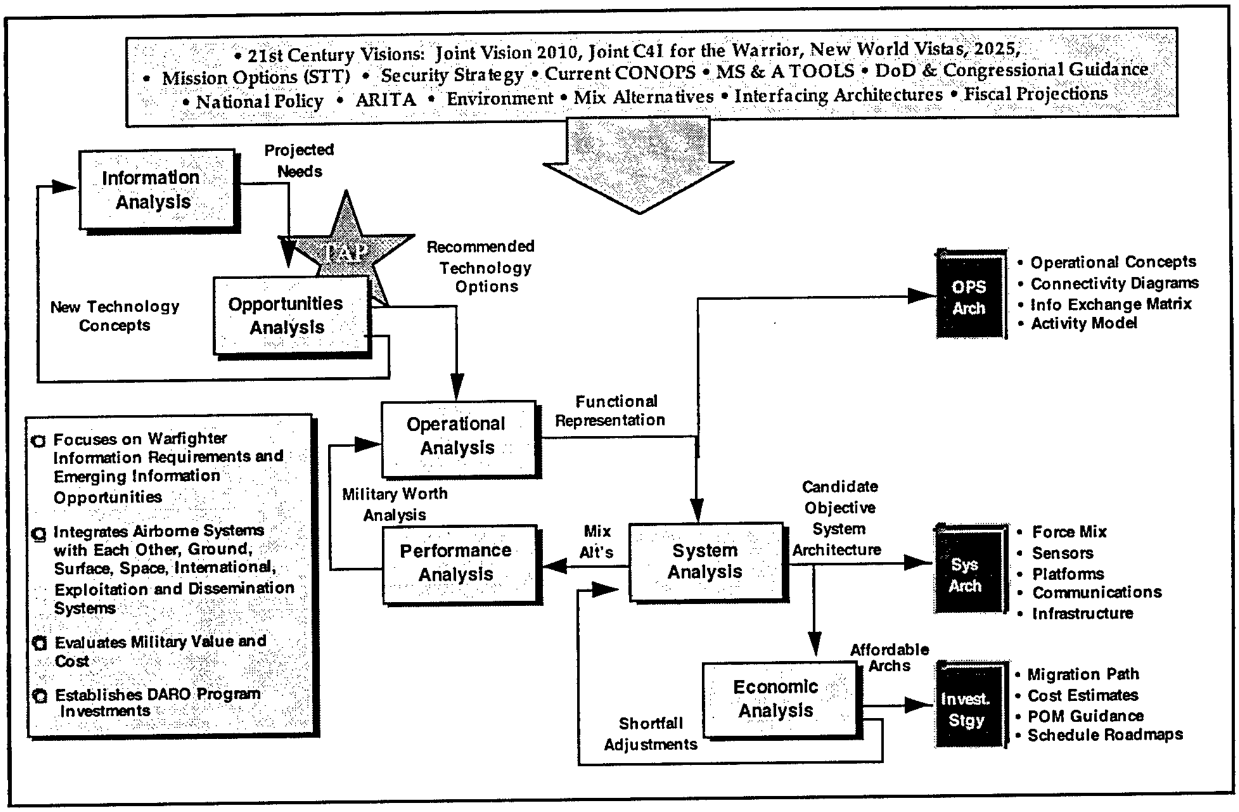

Figure 1-1. Architecture Development Approach

At the top of Figure 1-1, the wide array of vision documents for military operations in the next century are identified. These documents supported an information analysis, which provided an understanding of projected needs of the warfighter at all echelons of command in 2010 and beyond. The DARO's Advanced Technology Division and the DADT's Technology Advisory Panel assisted the DADT in the opportunities analysis to identify technology opportunities for satisfying projected needs. These opportunities are summarized in Table 1-1. The enumeration of functions to satisfy needs and their representation in terms of functional-flow block diagrams occurred during the operational analysis phase of the design effort. The DADT captured the operational architecture view in a computer-aided systems engineering tool for designing and documenting systems. The physical elements needed to perform the functions defined by the functional flow descriptions were selected by the DADT in the systems analysis phase. The resulting architectures and force mix alternatives were evaluated in the performance analysis (modeling and simulation) phase of the study, with particular emphasis on assessing military worth

Table 1-1. Technology Investment Areas Critical to the Vision Architecture

Recommended Investment Area	*Capability Enhancement*
Global network communications	• Network-centric collaborative collection and value-added analysis • Internet-like warfighter information pull and advisory push • Concurrent, collaborative operations and reconnaissance planning
Precision geolocation	• Accurate emitter location provides cues for imagery search problem • Precise location of imaged targets allows "bomb on coordinate"
Machine-aided target detection and recognition	• Extract critical information faster to support warfighter timelines
Improved electro-optical and synthetic aperture radar sensors	• High quality imagery at long standoff ranges • Broad area coverage • Lighter weight, reduced power consumption
Improved platform survivability features	• Lower observability • Increased survivability through higher altitude, higher speed
Moving target exploitation	• Find, track, and classify movers in Moving Target Indicator scans
High data rate com-munications via satellites	• Reachback to exploitation resources based in the continental United States
Multisensor integration	• Allows collaboration among unmanned aerial vehicles (UAV), unattended ground systems, and space during the collection process • Focuses exploitation resources on high priority areas • Elimination of single-sensor false alarms; improved target classification confidence
Multi-spectral imagery and hyper-spectral imagery sensors	• Defeat of concealment/deception countermeasures • Cueing into key areas of broad area imagery
Synthetic aperture radar processing	• Super-resolution processing allows target classification in wide-area search • Target information gained from use of phase information
Airborne communications node reconnaissance applications	• Reachback to exploitation resources in the continental United States • Direct dissemination to warfighter
Reliable over-the-horizon communications on commercial networks	• Employ the redundancy offered by multiple commercial links to obtain robust, assured communications
Platform-independent user tasking software	• Allows warfighter to request information without consideration of features of specific collection platforms
Embedded real-time simulations	• Simulation of underway and planned missions to improve collection efficiency
Secure intelligent software agents	• Warfighter transmittal of embedded analysis software to query remote sites
Integration of manned and unmanned flight regulations	• Streamlined qualification and certification for UAV flight in civil airspace

at the campaign level. These activities were followed by a detailed economic analysis that developed the system life-cycle cost values for cost-benefit tradeoffs and for analysis of costs versus budgets to establish affordability of the architecture alternatives. Finally the DADT will produce an investment strategy for acquiring the vision architecture employing multiple, viable migration paths.

The architecture design was guided by the DoD's Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Architecture Framework (CISA-0000-104-96). The details of the application of this framework are presented in Section 2. This framework describes an architecture by three distinctive, but related, perspectives or views, which determine the characteristics of the architecture (Figure 1-2). The operational architecture view identifies the functions that must be performed to satisfy warfighter needs. The system architecture view identifies the physical components necessary to perform the functions defined by the operational architecture view. The technical architecture view identifies the standards for "wiring together" the components defined by the system architecture. [The DARO has published its technical architecture view in the form of the Airborne Reconnaissance Information Technical Architecture (ARITA)].

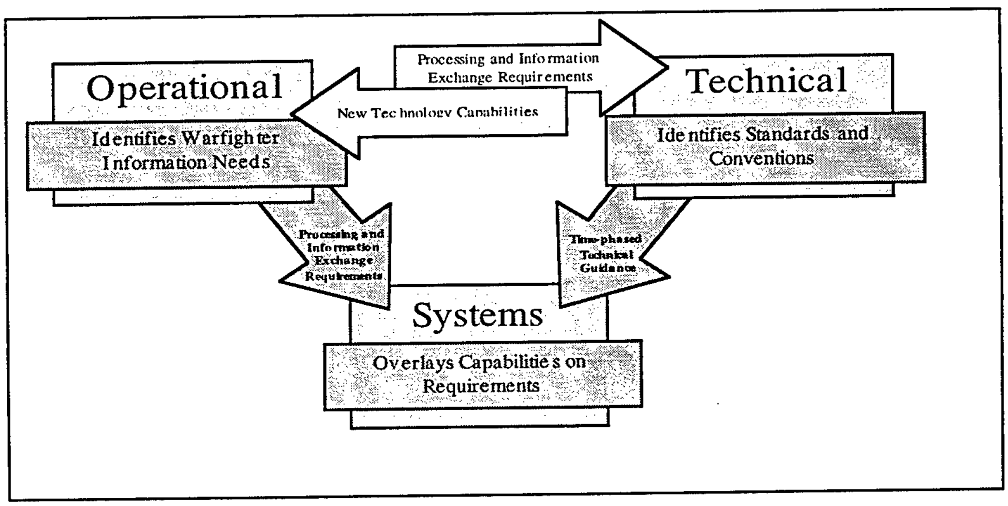

Figure 1-2. The C4ISR Architecture Framework Provides a Standard for Describing Architectures

By following the approach described above, the DADT produced the vision architecture and a selection of the products defined in CISA-0000-104-96. The major attributes of that architecture, and a summary description of its two key segments, are presented in the subsection that follows.

1.2 THE VISION ARCHITECTURE

1.2.1 General Description

The proposed architecture exhibits a ubiquitous form of internetting and a network-centric concept of operations. This type of architecture enhances real-time delivery of information to warfighters. It enables the warfighter to become the "front-end" of the architecture and the "analyst of choice." The architecture leverages commercial and coalition products and services and can inject new capabilities without major expenditures (i.e., it has a low cost of entry). Various operating domains can be reconfigured rapidly. In addition, it enables collaborative planning that allows both "smart" information push and user pull. Additionally, the architecture operates as an enterprise that is market-driven to provide service to customers. The physical systems of this vision architecture are viewed as components of a network-centric, internet-like information delivery system (see Figure 1-3).

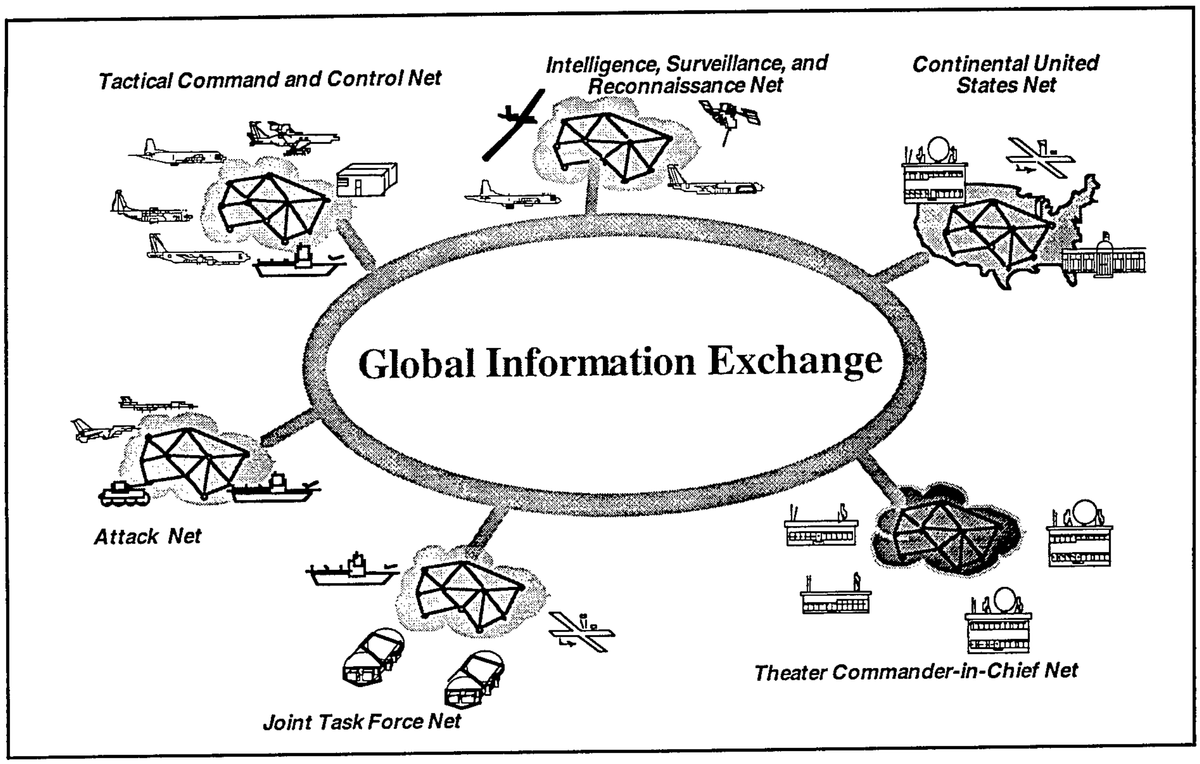

Figure 1-3. Future Global Networking Enables the Vision Architecture

In this view, collection platforms, processing, exploitation, and dissemination centers are treated as local and wide area networks distributed on a global backbone. Enterprise database connectivity forces a merger of information databases and communication techniques and blurs the design distinction that now exists between the two. The current paradigm of intelligence product delivery-push, supplemented with the ability for the warfighter to check delivery status of a request for information, is replaced. Instead, the focus shifts to process management for:

- control of "smart" system-push and selective warfighter-pull information transactions over distributed data resources
- transaction boundaries that are transparent to the warfighter, thus allowing access by specialized ISR application software to multiple information databases
- support of concurrent multiple transactions that share network resources
- multilevel security control over a mix of classified and unclassified material in an internet-like environment

Management of relational and object-oriented databases, their connectivity and interfaces, and user transparency to data types become central features of the architecture. The subnets of this Global ISR Enterprise include space nets, continental United States (CONUS) nets, and extended coalition-based nets, all linked together to serve major theater-of-war-based networks for warfighters and shooters, as well as serving national level production of intelligence.

As envisioned, the future theater commander will be supported by an agile theater-level internet that is lightweight, rapidly deployable, and easily reconfigurable; it requires minimal logistical support. To support forces on the move and provide connectivity to isolated forces, it will be truly mobile. The theater nets of the future will provide ubiquitous lines of sight: (e.g., aircraft-to-aircraft, space and ground; theater forces to aircraft and to space). Worldwide points of entry to the Global ISR Enterprise will be available for any likely location of a theater. The theater-level internet can therefore project global networking services into the tactical theater, maximize the use of commercial systems, and provide a means for the warfighter to be an analyst of choice as an active member of the information workgroup. The end result is a "cybertecture" that integrates information with warfighter operations (see Figure 1-4).

The vision architecture, which is described in greater detail in Section 2 and Appendices F and G, captures much of the functionality needed to enable the operational attributes discussed above. Maturing versions of this initial architecture will fill in additional detail and capture input from the services, commanders-in-chief, and Joint Staff. The DARO's early design work has maintained flexibility to accommodate changes in operating concepts and changes in threat. The physical instantiation of the architecture can be adapted to a spectrum of operating concepts, from conservative, but more efficient, versions of the way business is done today to bold introduction of competitive market forces that offer the promise of driving down the cost of delivering ISR information to the warfighter. In fact, an internet-like, network-centric architecture that invites a competitive global information exchange in support of the warfighter will migrate the ISR community into new aggregations of information workgroup elements (see Figure 1-5).

Subcommunities can be expected to emerge comprised of information brokers, producers, and consumers all supported by value-added resellers and regulators, and functioning in a network environment that enables global ISR information exchange. This environment will be provided by enterprise operating system software that mirrors the cost effective way global corporations collect, process, exploit, and disseminate information through worldwide networks. The functions performed by these emergent market-driven subcommunities are described in Table 1-2.

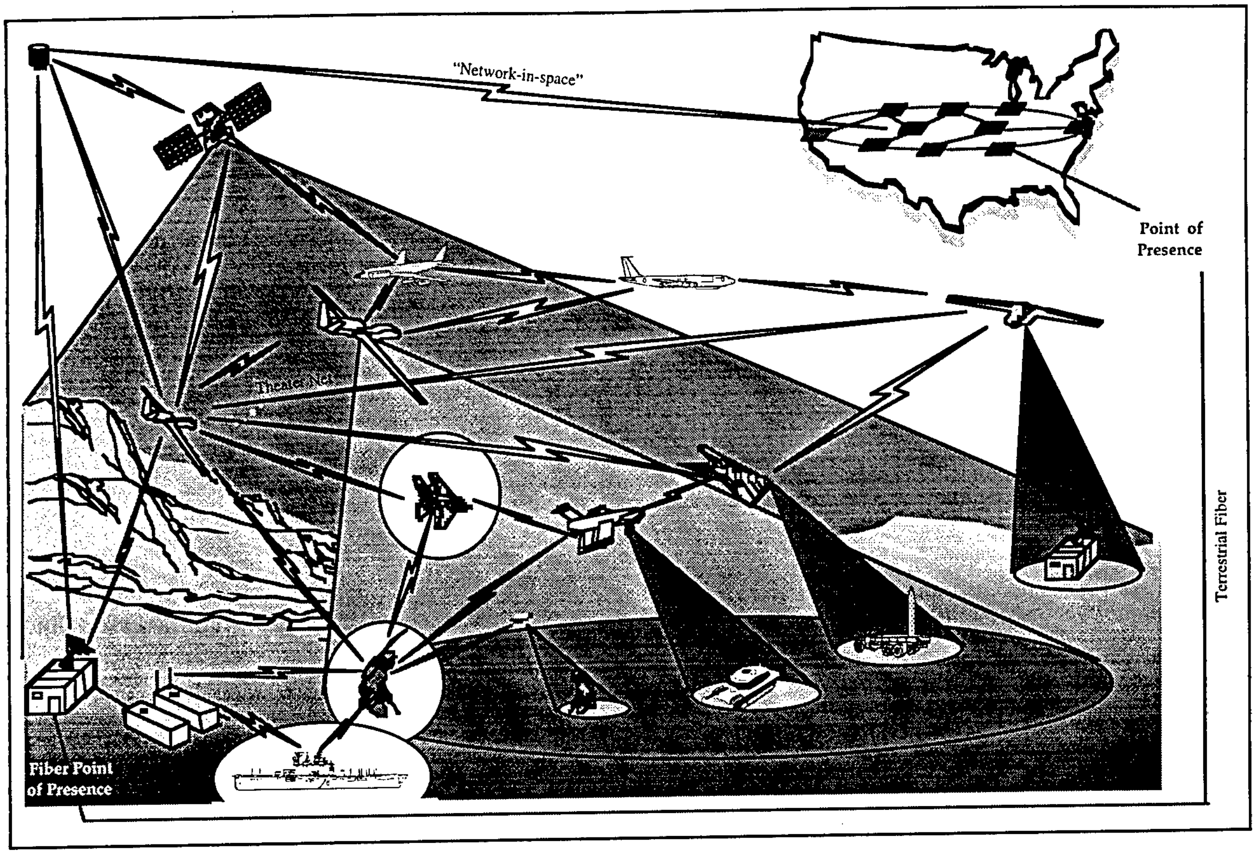

Figure 1-4. Vision "Cybertecture" Integrates Information With Warfighter Operations

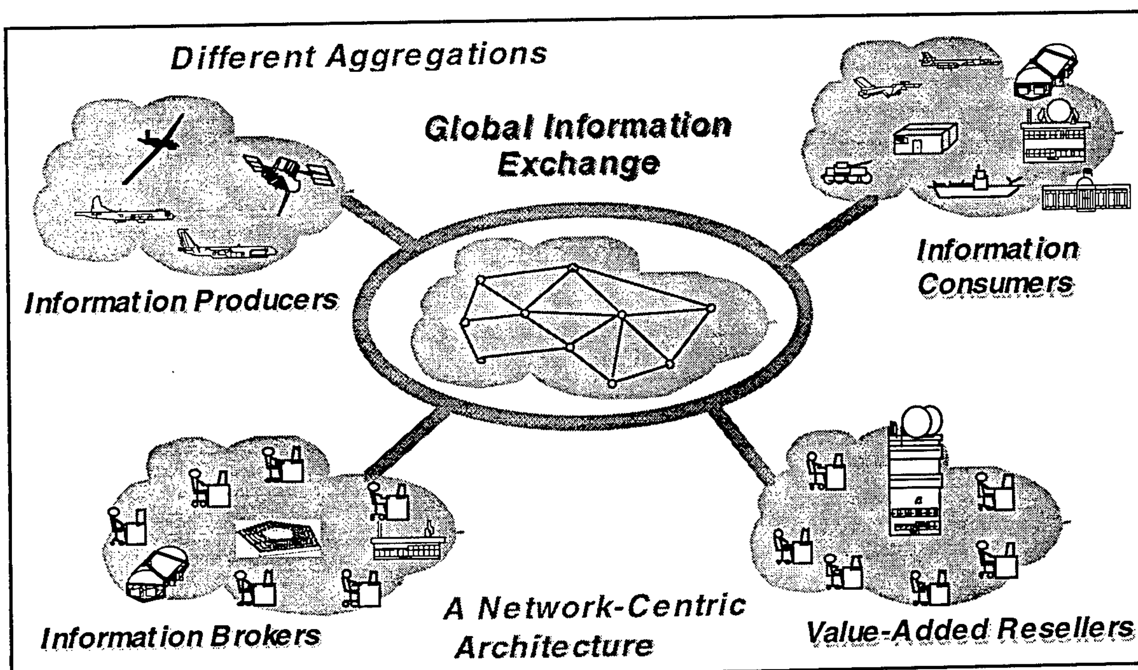

Figure 1-5. The Vision Architecture Allows New Aggregations of Information Workgroups to Support the Warfighter

Table 1-2. Information Workgroup Elements of the Global ISR Exchange

• **Information Consumers**—Any warfighter from the National Command Authority down to the individual soldier (U.S. or coalition)
• **Reconnaissance/Surveillance Product and Service Information Producers**—Operators of airborne (and satellite) collection systems (military and commercial) and first level processing facilities
• **Value-added resellers**—Process data and information into a form that meets the needs of a specific class of target consumers
• **Information Brokers**—Facilitate transactions between consumers, providers, and value-added resellers. This involves maintaining credentials of value-added resellers and providers, and interpreting needs of specific classes of consumers
• **Exchange Regulators**—Establish and enforce rules and regulations for operating and using the global ISR information exchange

1.2.2 Description of the Two Major Segments

The vision architecture that has been described consists of two major segments: (1) the platforms and sensors segment and (2) the distributed reconnaissance infrastructure segment. These segments are described below.

1.2.2.1 The Platforms and Sensors Segment

The DADT examined the missions performed by today's numerous airborne reconnaissance platforms and grouped them into classes that share common characteristics. This analysis was not constrained by traditional/parochial service platform-mission viewpoints. The defining characteristics of each class are listed in Table 1-3, along with examples of platforms in each class and the benefits each class of platforms provides to the warfighter.

Opportunities for joint application of platforms, across separate missions and among separate services, were identified and examined in the process of selecting potential platforms for the vision architecture. In several cases, platforms were identified that could host several mission types, thereby consolidating multiple aircraft types. In other cases, possibilities for consolidation were identified and left open for subsequent evaluation when adequate information becomes available.

The candidate platforms identified in the vision architecture presented in this report are characterized by consolidation and migration toward fewer platform types and eventual dominance of the airborne ISR mission by unmanned aerial vehicles (UAVs). For example, the numerous signals intelligence analysts on board today's large manned platforms may be able to operate on the ground in the future. This is the first step in moving various mission functions to smaller platforms or combinations of other platforms. Also the missions now performed by the diverse collection of these large manned systems should be consolidated on a few new, common aircraft types. Moving portions of the functions to other platforms, as well as payload size-weight-power reduction through technology development, may enable transition of the remaining functions to smaller aircraft. Four separate tactical reconnaissance pod programs should be unified with common sensors into a single pod, or a family of closely related pods, carried by the Joint Strike Fighter. As a final example, advanced versions of high altitude UAVs should be considered.

Table 1-3. The Classes of Airborne Platforms in the Vision Architecture Provide a Broad Range of Capabilities to the Warfighter

Platform Class	Defining Characteristics	Specific Platform Examples	Benefits to Warfighter
High Altitude	• Operation at high altitude, either standoff or penetrating • Moderate payload capacity	• Enhanced Global Hawk • Enhanced DarkStar • U-2S	• Increased survivability • Wide Field of View • Extended Endurance
Commercial Jet	• Operation at medium altitude; overlap with flight regime of commercial passenger and cargo aircraft • Substantial payload capacity	• Business Jet (e.g., Gulfstream IV) • C-130J or variant • Future C-135 replacement	• Near continuous moving target information • High capacity signals intercept for situational awareness • Precision payloads for measurement/ characterization of threat order of battle
Large Turboprop	• Medium/low altitude operation • Low profile operation due to commonality with non-reconnaissance aircraft • High payload capacity	• C-130J or variant	• Ability to collect desired imagery and signals in low threat environments
Mid-Weight	• Low-medium altitude operation • Moderate payload capacity • Greater deployment flexibility (shorter runways)	• Common Support Aircraft (Navy) • Aerial Common Sensor (Army)	• Increased availability due to smaller size • Situational awareness, threat warning, and targeting at short range
Pods	• Low-medium altitude operation • Moderate threat survivability • High airspeed	• Uninhabited Combat Air Vehicle • Joint Strike Fighter Pod • F/A-18 Pod	• Increased availability due to integration with other unit functions • Threat survivability • Rapid response • Under-the-weather electro-optical imaging
Medium Altitude Endurance	• Medium altitude operation • Moderate payload capacity	• Medium Altitude UAV	• Continuous coverage
Staring Reconnaissance	• Low-medium altitude operation • Low payload capacity • Slow airspeed	• Medium Altitude UAV • Tactical UAV • Vertical Take-off and Landing UAV • Mini-UAV	• Small size enables portability • Continuous coverage • Low cost enables great proliferation

1.2.2.2 The Distributed Reconnaissance Infrastructure Segment

The distributed reconnaissance infrastructure consists of the collection management, processing, exploitation, and dissemination systems for the vision architecture. Table 1-4 defines the major infrastructure elements. Node connectivity and networking for the infrastructure is provided through a global ISR information exchange network environment (GIIENE). This network would provide global access to ISR data and information for the various operating domains. The GIIENE provides two windows into the environment: the GIIENE Browser and the GIIENE Organizer/Director. The GIIENE Browser enables users (consumers, providers, value-added resellers, brokers, and regulators) on workstations to interact with network databases and each other. Mapping software is keyed to a specific user's view of the battlespace, using coordinates and terms of reference familiar to that user. The GIIENE Organizer/Director enables the regulators to exercise their network monitoring and control responsibilities.

The planning and processing systems of the distributed reconnaissance infrastructure are defined by the remaining three elements in Table 1-4. The Distributed Mission Control and Operations element is used by ISR information producers to control collection platforms and sensors. The Distributed Mission Tasking and Planning software provides the mechanism for producers and consumers to collaboratively plan and task reconnaissance assets. The Distributed Value Added Exploitation element provides the route for value-added resellers to interact with the GIIENE and deliver services to the users.

Figure 1-6 is a network representation that integrates the collection systems with the distributed reconnaissance infrastructure. In summary, the distributed reconnaissance infrastructure holds the mechanisms for ensuring that information is delivered to warfighters and that the elements of the infrastructure provide access from many locations to ISR information.

1.3 MIGRATION TO THE VISION ARCHITECTURE

In this subsection, we summarize work done to date to size major segments of the vision architecture to meet future warfighter needs. We also discuss options for migrating from current capabilities to 2010 and beyond.

The architecture as described addresses airborne reconnaissance capabilities for the future, particularly focusing on 2010 and beyond. However, changes are proposed that should occur during the next decade. The realities of today's highly intense levels of employment for the reconnaissance forces, and the postulated increase in peacekeeping missions and other vital but noncombat uses of DoD assets, made the DARO extremely conscious of the need to maintain on-going reconnaissance capability during transitions. Therefore, the goal was to outline a strategy to effectively move from today to "tomorrow," sometimes by modernizing existing systems and sometimes by recognizing that current systems will simply not suffice in the post-2010 environment. In other words, the superb collection and dissemination systems of the 1980s and 1990s, which were developed for a Cold War environment, may not be the best choice for the rapidly changing information warfare age of the next century.

The DADT approach to migration, described in Section 3, is summarized here. The DADT integrated the existing baseline and currently planned airborne reconnaissance programs that are "on the books today," i.e., programmed in the Future Years Defense Plan, with a substantive vision of what is needed in 2010 and beyond. The migration of both segments of the architecture

Table 1-4. The Distributed Reconnaissance Infrastructure Holds the Mechanisms for Ensuring Information Is Delivered to the Warfighter

Architecture Element	Primary Functions	Components
GIIENE Browser	• Provide user specific view (access) of ISR data and information in a form that enhances understanding of that information	• "Internet" Browser • Mapping Software • Database Interface
GIIENE Organizer/Director	• Create domains, set up firewalls, monitor GIIENE status, and assure quality of service	• Network Management Software
Distributed Mission Control and Operations "DMCO"	• Control airborne collection platforms and sensors • Receive data from airborne reconnaissance and surveillance platforms	• Database Server • Mission Recorder • GIIENE Gateway • Miniaturized Interoperable Surface Terminal • Pilot Workstation • Payload Workstation
Distributed Mission Tasking and Planning "DMTP"	• Develop plans for airborne reconnaissance and surveillance platforms, collaborating with operations • Support dynamic tasking of platforms and sensors	• Module for Tactical Airborne Reconnaissance Pod System • Module for Air Force Mission Support System • Module for Distributed Mission Control and Operations
Distributed Value Added Exploitation "DVAE"	• Analyze reconnaissance/surveillance data and information	• Exploitation Workstation • General Applications Server • INTEL Database Server • Multi-Intelligence Exploitation Manager • National Input Segment • Reference Database Server

is discussed below. Migration of the platforms and sensors segment (which usually receives prominent attention) is treated first, followed by the proposed migration of the distributed reconnaissance infrastructure.

1.3.1 Migration of Platforms and Sensors to the 2010 Force Structure

Several alternative (and viable) 2010 ISR force mix options of platforms and sensors are described in detail in Section 3. Each is sized to satisfy the strategy to fight and win in two major theaters of wars. To support this 2 MTW strategy, an increase in force mix from current levels is required. Other missions, namely peacetime engagement and deterrence and conflict prevention, are supported by drawing from the inventory acquired to fight and win in two major theaters. As a specific example, Table 1-5 presents the 2010 force structure projection alternative that reflects a movement to a UAV-dominant role in airborne ISR. A migration roadmap leading to this mix of platform types is shown in Figure 1-7.

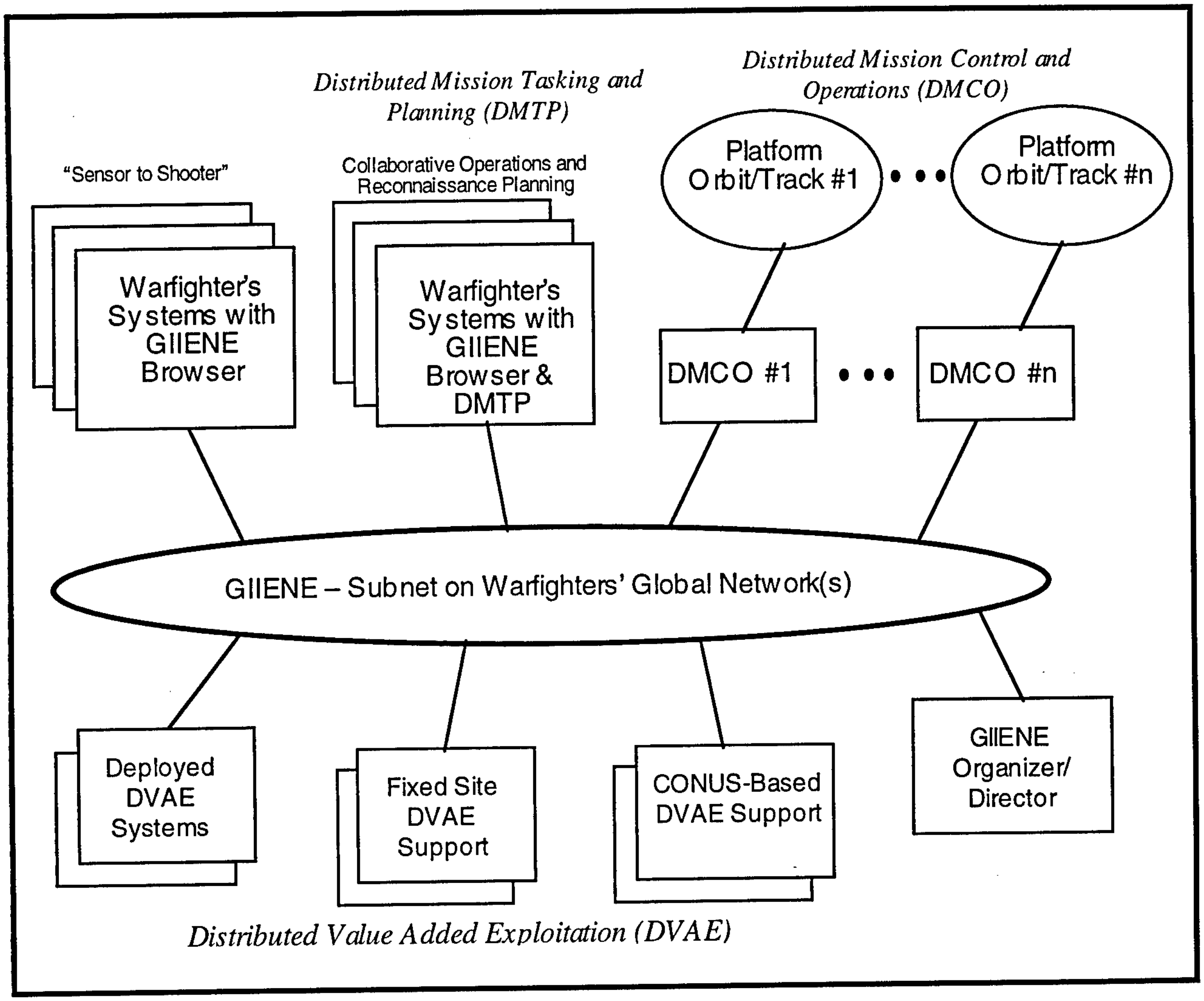

Figure 1-6. The Distributed Reconnaissance Infrastructure Elements Provide Distributed Access to ISR Data and Information

In projecting ISR force mix options and their associated migration timelines, the DADT took an aggressive view of platform and sensor evolution, but tempered the projected 2010 outcomes with a realistic appreciation of acquisition schedule issues and cost challenges involved in reaching initial operational capability for new systems by 2010. The force mix option presented in Table 1-5 to illustrate the vision architecture assumes both the success of the high altitude endurance UAV technology demonstrations and the decision to introduce this capability into operations as rapidly as feasible. Less aggressive alternatives are analyzed in Section 3.2 and Appendix B.

Table 1-5. UAV-Dominant 2010 Force Structure Projection

Altitude Regime and Platform Types	Number of Platforms	Discussion
High Altitude		UAVs replace manned platforms in long range HAE all-weather-sensor ISR operations. By 2003 the Global Hawk (with image intelligence) augments the U-2 for the standoff missions, while the DarkStar fills the SR-71 void for the penetration missions. Subsequently, the HAE UAV (new or modified Global Hawk with image and/or signals intelligence) completely replaces the U-2 by 2010. The projection also adds an HAE UAV to provide ACN capabilities.
Multi-INT HAE UAV (or Single-INT)	21 (or 35)	
HAE ACN UAV	12	
RQ-3A DarkStar UAV	14	
ACN = airborne communications node; HAE = high altitude endurance		
Medium Altitude		The Predator UAV is maintained and enhanced through 2010 with image intelligence sensor improvements and possible incorporation of a capability for signals intelligence. During 2008-2010, there is an initial reduction in the RC-135V/W from the current 16 to 12 platforms, depending on the HAE UAV capability for signals intelligence and Air Force plans for C-135 replacement or consolidation of missions flown by C-135/707 variants. A new C-130J(R) common, reconfigurable aircraft concept is introduced by 2007 to replace REEF POINT, PACER COIN, and SENIOR SCOUT mission capabilities, but this could be accelerated by using some of the C-130Js recently appropriated by Congress. The Army's Aerial Common Sensor concept is accelerated to replace the Airborne-Reconnaissance-Low capability and GUARDRAIL, with initial operational capability in 2007 but a mix of all three systems remaining in 2010. The Navy's concept for a Common Support Aircraft is part of the long-term migration with actual implementation occurring around 2014. Therefore, no platform changes supported by the Common Support Aircraft are indicated in the 2010 force projection.
E-8C JSTARS	16	
RC-135V/W RIVET JOINT	12	
RC135(S), COBRA BALL/COMBAT SENT	3/2	
EP-3E ARIES II	11	
C-130J(R)	10	
ES-3A SHADOW	16	
RC-7 Airborne Reconnaissance Low (ARL)	8	
RC-12 GUARDRAIL	24	
Airborne Common Sensor	12	
RQ-1A Predator UAV	48	
Medium to Low Altitude		Tactical UAVs and improved dual-role fighter reconnaissance capabilities are added. UAVs are fielded in large numbers beginning around 2000 with an Outrider version for the Army and a vertical takeoff and landing version for the Navy and Marines. The projection maintains and improves the current Marine F/A-18D ATARS and accelerates the delivery of Navy F/A-18F SHARP to 2003-2006, with complete phaseout of the F-14 TARPS by 2010. However, the projection reflects the eventual replacement of these systems by a multi-service common sensor pod for the Joint Strike Fighter, with initial replacement of the Air Force F-16 TARS around 2010. Later (i.e., beyond 2015) a reconnaissance variant or pod for an uninhabited tactical aircraft or uninhabited combat air vehicle configuration is envisioned.
Tactical UAV	276	
F-16/Joint Strike Fighter	20	
F/A-18D (Marines)	31	
F/A-18F (Navy)	50	

1.3.2 Migration of the Distributed Reconnaissance Infrastructure

Migration of platforms and sensors from today to the 2010 timeframe is only part of the migration story for the vision architecture. Migration of current networks, communications, and ground and surface systems to the distributed reconnaissance infrastructure of the global ISR enterprise forms the rest of the story.

Keeping pace with the explosive growth in information technology industries may well be the greatest challenge for migrating the distributed reconnaissance infrastructure. An era is beginning in which DoD must integrate commercially available information technologies (including computers, communications, information systems, networking technology, and software applications) rather than develop its own. And it must continue the integration process on a regular basis just to keep pace with new generations of this technology. Figure 1-8 summarizes the migration strategy. In conjunction with this evolutionary approach, the DADT devised a virtual

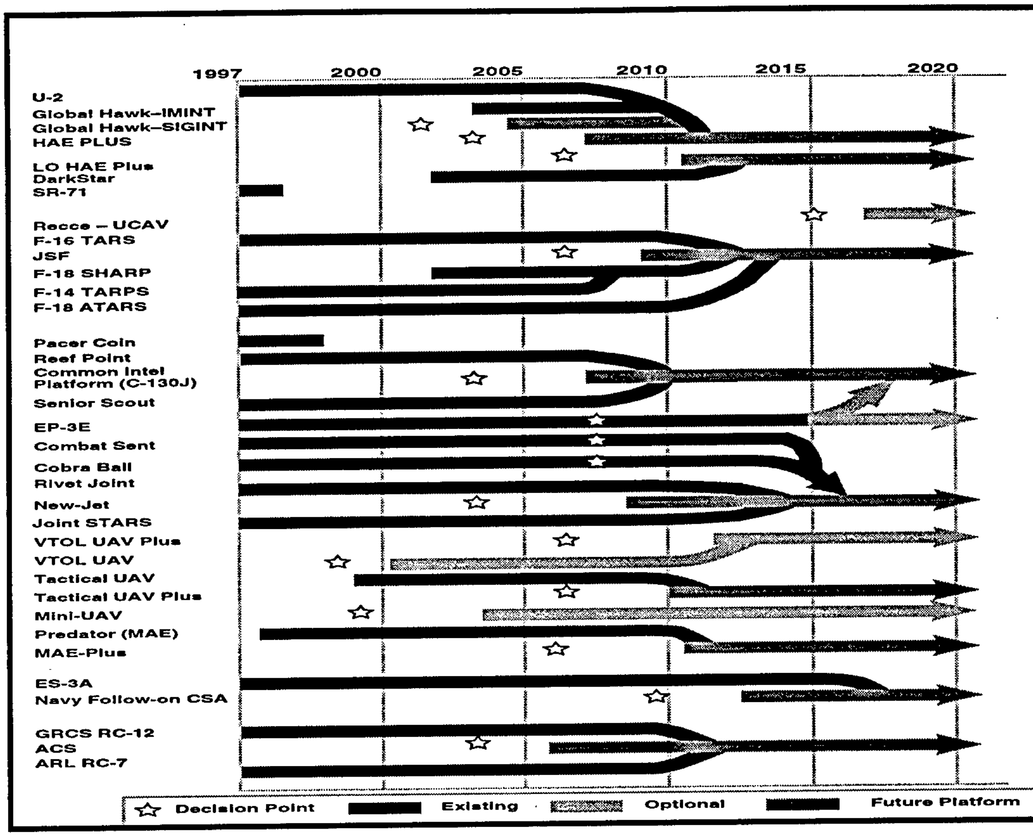

Figure 1-7. Platform Migration Roadmap for UAV-Dominant 2010 Force Structure Projection

proving ground approach to manage uncertainties in migration options and deal with a much faster pace of technology insertion than may otherwise be feasible (the virtual proving ground is discussed later in Sections 1.6 and 6).

The migration strategy for the distributed reconnaissance infrastructure encompasses ongoing guidance for migration from today's baseline architecture of independent processing, exploitation, and dissemination systems through current plans for multi-intelligence interoperability and consolidation. Ultimately, the infrastructure migrates to a completely integrated, distributed infrastructure that operates seamlessly over a worldwide network with warfighter and intelligence community systems.

Communications technology is a core enabler for the migration of reconnaissance infrastructure capabilities. The first step is migration *from* existing single-intelligence, service-specific ground and surface systems connected through primarily point-to-point communications links *to* multi-intelligence interoperable systems with distributed workgroups working collaboratively through network interconnections. Subsequent steps include addition of "software applications" that extend processing, exploitation, and dissemination capabilities into DoD systems

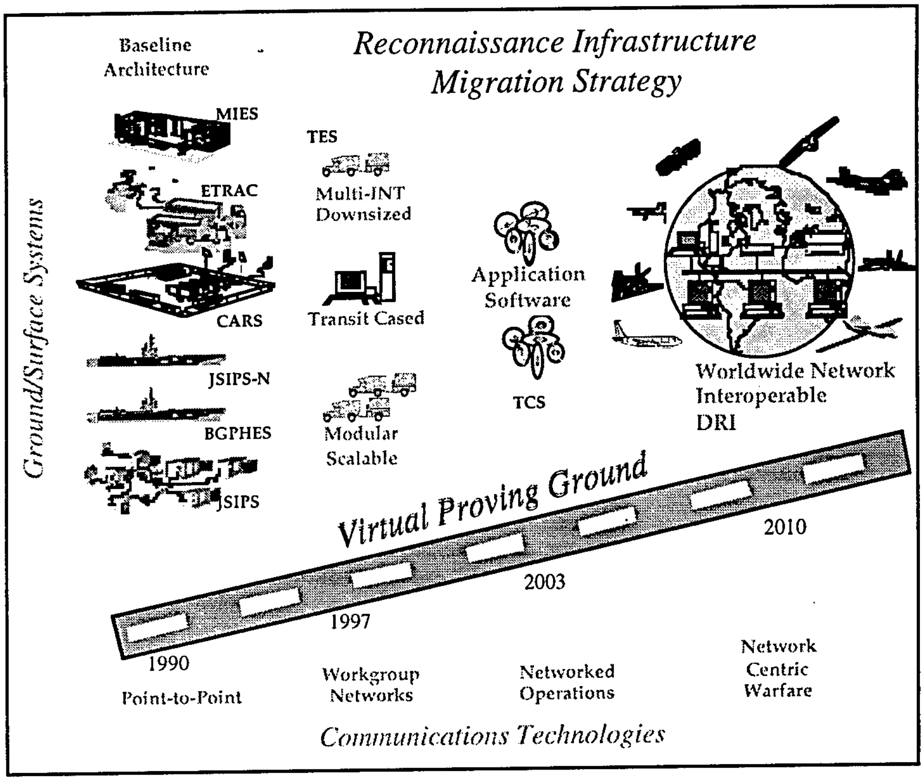

Figure 1-8. Migration of the Distributed Reconnaissance Infrastructure Combines Evolution of Today's Systems with the Virtual Proving Ground

beyond those under the direct oversight of DARO. The migration endpoint is fully networked operations supporting network-centric warfare. Other information technology advances such as the evolution of intelligent software aids and advanced, autonomous information systems will enable the increased use of onboard, distributed processing of raw data, which will further improve system throughput and responsiveness.

The migration strategy for the long term is founded on several design tenets. These prepare legacy infrastructure systems to "springboard" toward the vision architecture at a faster pace. They are not without risk, but conservative approaches to migration rarely generate revolutionary changes in the fielded enterprise. The design tenets are summarized in the paragraphs below.

Encapsulate legacy systems — Object-oriented technology can be used to encapsulate parts of legacy systems such that each part can migrate separately from its parent system. This technology also offers an opportunity to transfer the encapsulated functionality among subsystems in the overall enterprise, providing one way to move major functionality to additional or alternative places.

Co-migrate legacy and new databases — Information superiority is the key to unlocking military potential in the next century. This advantage cannot be achieved without implementing a sound information architecture. Understanding the baseline data structures, formats, and database schema is crucial to engineering the future information-oriented global ISR

enterprise. The ability to effectively migrate legacy databases into a future information enterprise, which is equally crucial, depends on technology that enables these legacy databases to operate concurrently in the same enterprise with new, more robust designs. This approach enables systems to migrate without sacrificing existing capabilities or losing data, as new information systems take over to keep pace with ever-increasing operational tempos.

Transition to open systems — This transition goes beyond implementation of standards in a conventional sense. It is not always appropriate to wait for one of several competing technologies to "win" in the information technology marketplace before implementing the functionality. In the realm of information technology, it is often advisable to try two or more competing "standards" before picking one for the long term. For example, it may be wise to incorporate multiple networking technologies — such as ATM (asynchronous transfer mode) *and* fibre channel — and determine where each works best and how they may work together in the larger enterprise. If, over time, one standard dominates the market, DoD can simply go with the winner.

Commingle multiple versions — During migration, multiple versions of similar or equivalent technology will exist in the ISR enterprise at the same time. To achieve migration objectives throughout the entire, complex enterprise and keep pace with ever-changing commercial information technology products, the military and intelligence communities can no longer maintain "frozen" configurations of systems. No two systems will be exactly alike. DoD needs new procedures to manage rapid migration, in some cases allowing end-users to upgrade while maintaining overall configuration accountability.

The distributed reconnaissance infrastructure is a complex system-of-systems that will undergo many changes (some radical) in its migration to the airborne cybertecture envisioned for 2010 and beyond. During this migration process the overall DoD and intelligence community architectures will also undergo many changes commensurate with new and evolving concepts and innovations. In keeping with these changes, the distributed reconnaissance infrastructure migration is viewed as occurring over five architectural phases (see Figure 1-9). These phases have a high degree of overlap commensurate with realities of architecture migration. Not all components of the overall system-of-systems can be migrated on the same timeline, nor will all components be of the same technical maturity.

The current architectural phase, Phase I, began with the Common Imagery Ground Surface System initiative and is presently affecting upgrades to existing systems and development of new infrastructure elements. The kick-off for Phase II occurred in August 1997 with the first meeting of the Distributed Common Ground System Integrated Product Team. At about the same time, Phase I was expanded by starting the Joint Interoperable Operator Node (JION) and Joint Airborne Measurement and Signals Intelligence Architecture (JAMA) initiatives for further developing architectures for signals intelligence and airborne measurement. Phase III provides a bridge between current plans and the vision architecture by providing an evolutionary step between the Distributed Common Ground System and the distributed reconnaissance infrastructure. Phase IV provides an initial distributed reconnaissance infrastructure capability with collaborative planning and networked operations. However, the level of automation during this phase may be limited, so warfighters at lower echelons may not receive a full set of services. Phase V provides the full automation support of an intelligent network. Although these five phases are shown in the figure as a linear evolution, many of the goals for each phase may be achieved earlier than shown. For example, the virtual proving ground may help accelerate this migration by demonstrating new concepts that tie in with other advanced DoD initiatives more directly, so portions of the automated distributed reconnaissance infrastructure (Phase V) could be implemented by the middle of the next decade.

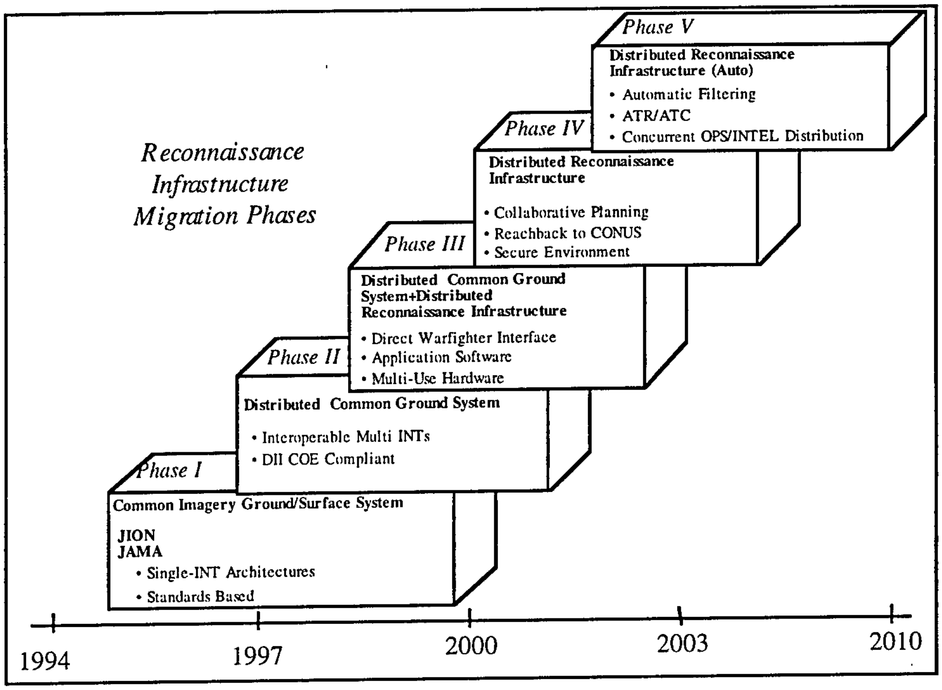

Figure 1-9. The Infrastructure Will Migrate Through Five Phases in Keeping with DoD and Intelligence Community Architecture Evolution

DARO's Common Data Link program is the crucial link between the platforms and sensors and the distributed reconnaissance infrastructure. This link provides the channel for injecting collected sensor data into the GIIENE and the back-channel for effecting warfighter command and control over the airborne reconnaissance fleet (warfighters' telepresence). As the distributed reconnaissance infrastructure proceeds through the migration phases, the Common Data Link could migrate to provide warfighter network node capabilities, enabling airborne reconnaissance systems to extend global networking down to tactical levels. At this stage, networks based on the Common Data Link will operate in hostile, adverse environments where both subscribers and nodes are highly mobile. Airborne reconnaissance systems will not merely be network subscribers, they will become part of the network fabric supporting the warfighters.

1.4 PERFORMANCE ANALYSIS

1.4.1 Road Map

Section 4 documents DARO modeling and simulation efforts to assess architecture performance, with particular emphasis on the campaign-level military worth of the ISR force mix. The insights gained from participation in joint studies with other organizations are also provided, as well as DARO assessments of related studies conducted by others in the airborne reconnaissance community.

Key thrusts of the DADT analysis effort were to: (1) identify modeling, simulation, and analysis tools available for airborne ISR architecture analysis and validate their capabilities to meet

ISR architecture study requirements; (2) employ the tools to analyze performance of potential airborne ISR force mixes; (3) evaluate the military worth of airborne reconnaissance in campaign scenarios; and (4) assess airborne ISR architectures through joint participation in other community studies.

A summary of the DADT results is presented in Section 4.1. The analysis provides new insights to the potential performance of alternative airborne ISR force mixes and clearly delineates complementary aspects of airborne and overhead collectors. Section 4.1 also illustrates the military value of airborne ISR in terms of its potential impact on campaign scenarios, and it suggests trades between ISR collection and processing, exploitation, and dissemination systems for improved support to future weapon systems. Specific modeling, simulation, and analysis tools used by the DADT for these studies are fully described in Appendix E, *DADT Modeling, Simulation and Analysis (MS&A) Program*, along with detailed analysis of the results produced with each tool.

Section 4.2 reviews airborne reconnaissance studies conducted by other organizations and summarizes DARO findings from joint participation in those studies. The most productive of these activities was the Integrated Spacecraft Aircraft Mix Studies, sponsored by the Plans and Analysis Division of the National Reconnaissance Office, which provided a joint forum for review of ongoing analyses in the Defense Intelligence Agency, Office of the Army Deputy Chief of Staff for Intelligence, Joint Chiefs of Staff, National Imagery and Mapping Agency, and DARO[1]. The Integrated Spacecraft Aircraft Mix Studies allowed analysts participating in related studies to communicate findings, share databases and tools, and exchange frank views on the various study directions and results.

As a result of these DARO modeling, simulation, and analysis activities, it became clear that improved tools and databases are needed to support future studies of airborne reconnaissance architectures. For example, most of the findings so far pertain to imagery collection, since little capability currently exists for analysis of other intelligence disciplines. These deficiencies are summarized in Section 4.3, along with a description of an initiative that will better position the DARO to lead the community effort to define the analytic tools essential to design of viable, relevant, airborne reconnaissance architectures.

1.4.2 Discussion of Results

The paramount modeling, simulation, and analysis challenge was to analyze future systems and processes in the context of the commander's decision cycle (Figure 1-10). Models of the physical systems and processes are needed for each key element of the architecture. Analysis of the total architecture would involve a fully interactive simulation of: (1) the key ISR elements used for *observation* of enemy activities (end-to-end intelligence process); (2) the process for development of information for *orientation* of the warfighter (perception of enemy forces); (3) the commander's *decision* process for strike planning; and (4) the employment of warfighting assets in *action* against enemy targets. As in an actual military engagement, the simulation should treat these processes interactively and iteratively to yield insight into the true military worth of various future architectures.

[1] The Integrated Spacecraft Aircraft Mix Studies Alliance was formed in January 1997 with the goal of allowing community organizations engaged in spacecraft or aircraft mix studies to share their data, insights, methodologies, and results. It was felt that if the various studies shared their approaches and data at the outset and throughout the effort, then there would be better understanding of the results or conclusions at the end. The idea grew out of an initiative by both the National Reconnaissance Office and DARO.

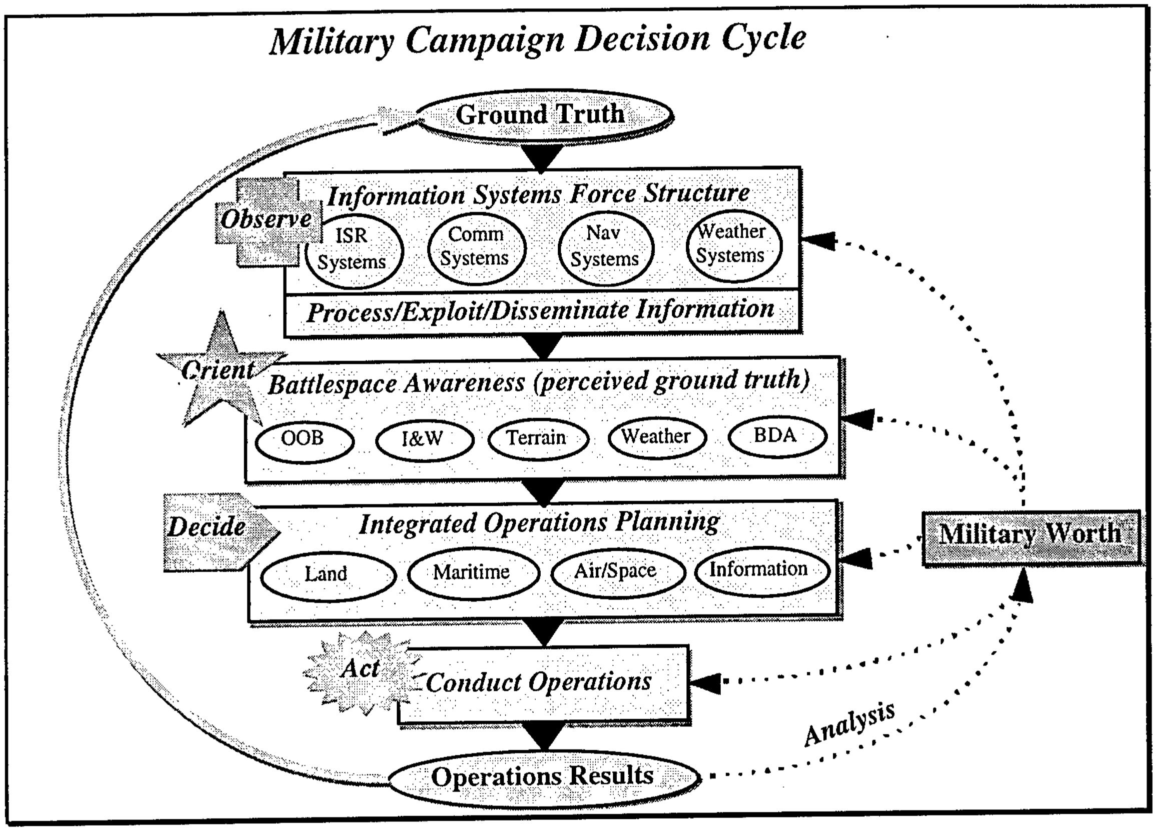

Figure 1-10. Military Campaign Decision Cycle

The DADT encountered a variety of studies that directly involve the DARO sphere of interest in evaluating force mix options for airborne reconnaissance. Figure 1-11 is an overall depiction of the breadth and depth of the contributing studies. Not all studies focused on the same level of support, nor did they employ the same metrics. Top-level conclusions drawn from the observations on these studies include the following:

- The ISR community is finally filling in the "big picture," but this is still a piecemeal process that focuses on individual studies and not the overall ISR picture.
- Although a capability for moving target indication may reduce the load on processing, exploitation, and dissemination, the impact on force mix needs to be better understood.
- Stealth fills a critical role at certain phases of the campaign.
- Satellites and aircraft fill different needs but are complementary: overhead is needed for denied access while airborne collectors are needed to meet tactical timelines.
- Communications and exploitation—not collection—are the real drivers in the world of Joint Vision 2010; none of these studies analyzed the ISR force mixes against a Joint Vision 2010 scenario.

- It is misleading to advocate architectural changes without considering the research and the engineering and manufacturing development needed to migrate affordably to the capability projected in some of the studies.
- Collection and production sources must be internetted; the continued use of "stovepipe" collection systems will consume unreasonable resources.

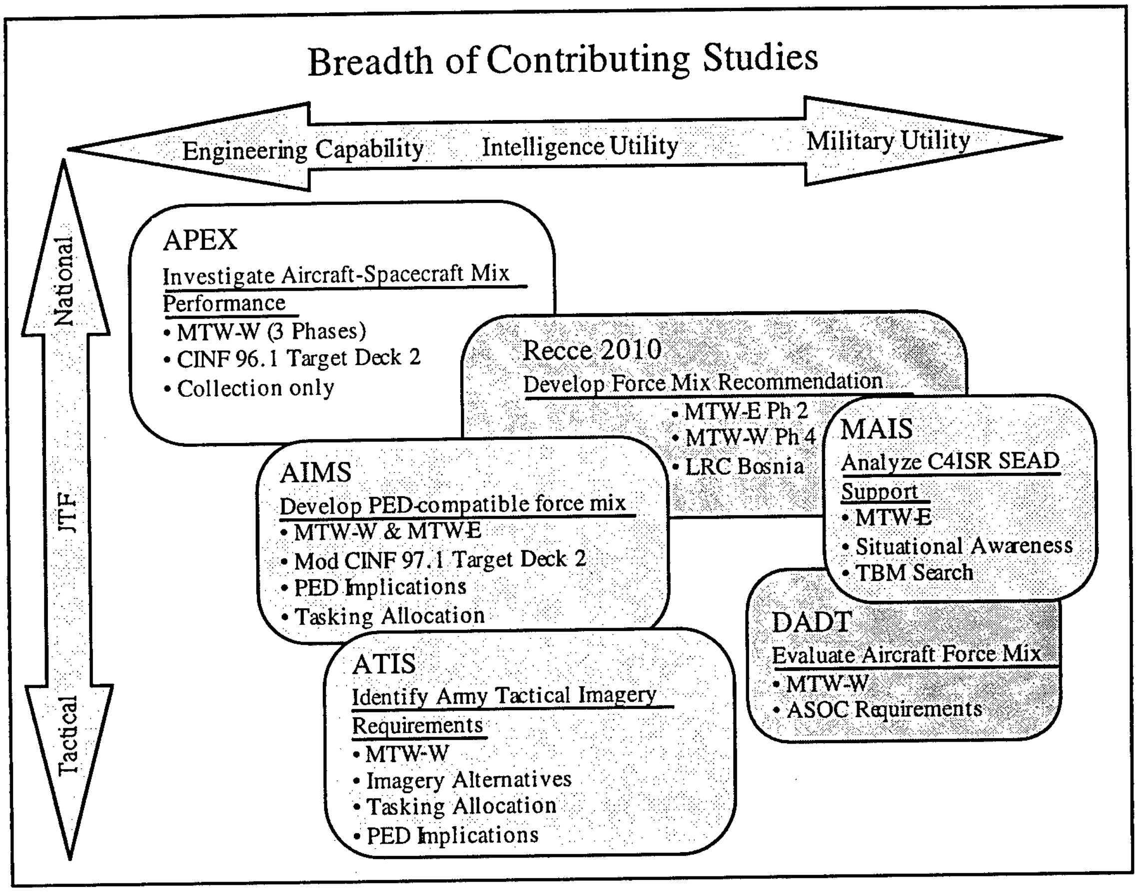

Figure 1-11. Breadth and Depth of Contributing Studies

A clear result of both the DADT activities and the participation in joint studies is recognition of the need for significant improvements in modeling, simulation, and analysis capabilities to support continued analysis and study of the architecture. Changes in the threat, the potential for further drawdowns of force structure, dramatic technological advances, and fundamental changes to joint operating concepts and the warfighting environment make it increasingly vital to examine and analyze the dependence of warfighting systems on information that is provided by ISR assets.

In response to shortfalls in analytic tools, the DADT developed a modeling, simulation and analysis initiative that spans the technical, mission, campaign, and military worth levels of airborne ISR modeling and simulation. The proposed initiative offers an achievable, "priced" project plan that DARO can endorse to achieve the objective, along with a discussion of next steps to

accomplish the plan. The proposal sets forth a vision and a plan for an initiative to develop and employ a family of ISR modeling, simulation, and analysis tools that will represent airborne reconnaissance objectively in context with other ISR options. A full-spectrum modeling, simulation, and analysis capability is needed as soon as possible to address key continuing events (e.g., budget issues, definition of sensible trades between manned and unmanned airborne ISR assets, and development of sound guidance to the services).

1.5 ECONOMIC ANALYSIS

An economic analysis focusing on life-cycle costs and affordability issues related to the vision architecture is provided in Section 5. A summary of that work is provided here.

1.5.1 Background

The DADT undertook its economic analysis to highlight and balance both the cost and performance impacts of the airborne ISR systems that were investigated. This was deemed absolutely necessary given today's pressure to address *cost as an independent variable* to lower the cost of ownership of military systems. A primary objective of the economic analysis was to develop a comprehensive annualized life-cycle cost estimate of ISR capabilities and use it for assessing cost and performance aspects of several candidate airborne force mixes within the vision architecture framework. The DADT economic analysis included the development of a discrete, annualized 14-year life-cycle cost estimate (FY1997 to FY2010) for each of the relevant airborne (and associated ground and surface) ISR systems included in the 2010 force structure projection. Life-cycle cost—as defined in DoD Directive 5000.4—includes the costs associated with the research, development, test and evaluation, procurement, operations and maintenance, and military construction phases of each ISR system.

Of particular interest was the current operating environment for existing manned reconnaissance platforms, which is characterized by high operational tempo, intensive personnel requirements, and continuing modification and upgrade programs to keep pace with emerging threats and changes in the nature of military operations. In addition, sustainment costs (mainly for procurement, operations and maintenance, and military personnel) for these manned ISR platforms and their associated sensors and dedicated ground and surface systems are a substantial portion of the total funding for airborne ISR. Attrition cost — the cost of replacing air vehicles that are lost or destroyed during *peacetime* operations — also needs to be included in total life-cycle cost.

No generally available and calibrated, community-accepted airborne ISR cost model exists today that can directly relate life-cycle costs with specific design parameters (e.g., range, speed, size) for architecture evaluations—across multiple airborne ISR systems. Furthermore, there are no existing databases that capture *all* of the life-cycle cost elements associated with airborne ISR systems—including both the airborne platform collectors and their corresponding ground and surface processing, exploitation, and dissemination systems. Given this current state of affairs, a primary objective of the DADT was to capture the existing parametric life-cycle cost data or estimates (including supporting rationales for the fiscal year 1998 budget) for the various systems that are included within the DARO's airborne ISR architecture responsibility. The data collected by the DADT included technical parameters (e.g., weight, size, speed), cost parameters (e.g., development, procurement, maintenance), and programmatics (e.g., schedule, buy profile, operational concept, planned improvements).

The DADT life-cycle cost estimate did focus on achieving the desired 2 MTW force mix by 2010 for all the airborne ISR systems included in the architecture framework. This meant that the DADT had to consider (in many cases, create) ramp-up, ramp-down, and "steady state" profiles

from 1997 through 2010 for each ISR system. These profiles became significant drivers of the life-cycle cost estimates.

1.5.2 Estimated Costs

Costs associated with the time-phased migration plan to 2010 for airborne ISR platforms, sensors, and related ground and surface systems were estimated. Costs associated with achieving the distributed reconnaissance infrastructure through modifying or augmenting ground, surface, and communication systems necessary for the universal availability of products provided by the 2010 ISR force mix were not estimated. However, costs were estimated for the virtual proving ground (i.e., the costs associated with planning and conducting various experiments or demonstrations of advanced concepts that may be incorporated into the vision architecture).

The details of the life-cycle cost estimates are in Section 5. In summary, estimated 14-year life-cycle costs of the platforms and sensors segment are $57 billion in then-year dollars. The costs for the distributed reconnaissance infrastructure are currently under investigation.

On the surface, there is a significant budget challenge to identify the funding necessary to implement the projected 2010 force mix. However, this may not be a valid concern. The DADT had difficulty in identifying all the procurement funding currently programmed across the DoD for airborne ISR systems. It was particularly difficult when service funding was not identifiable to specific platforms and systems. Due to the lack of complete budget visibility, it was not possible to conclude definitively whether the life-cycle cost of the 2010 force structure projection is affordable. Nevertheless, it was clear that a 2010 projection to support two major theaters of war drives the total cost of the architecture and presents much of the budget challenge.

The DADT conducted several force mix excursions that provided insights into potential ways to reduce life-cycle cost. Not all of the excursions were oriented toward lowering life-cycle cost. Several examined the impacts of using different approaches to accomplish the ISR mission envisioned for 2010 and beyond. Although some of these excursions yielded high life-cycle costs from 1997 to 2010, they appear to offer lower costs beyond 2010. The top-level conclusions based on these excursions are summarized below.

The life-cycle cost of the 2010 force mix would be significantly reduced (nearly 20 percent) if it supported one major theater instead of two. The 2010 force mix projection was designed to maximize satisfaction of the requirement to fight and win in two major theaters; the projection did not just minimize life-cycle cost. However, the DADT recognizes the need for fiscal realism and thus believes the projected force mix is a reasonable estimate of the cost for satisfying a two-theater commitment for airborne ISR.

1.5.3 Additional Insights

The DADT identified several new systems and variants of existing systems (e.g., a multi-intelligence, high altitude, high endurance UAV and a reconnaissance version of the C-130J) for which the probable costs have been estimated, but for which no budget is identified. The inclusion of the costs of these systems in the life-cycle cost estimate magnifies the apparent funding shortfall after the Five Year Defense Plan period. There also appears to be significant under-reporting of operations and maintenance and personnel funding budgeted for all UAVs in the DoD database, which further lowers the base for projecting the budget for the 2004 to 2010 timeframe. This situation indicates the uncertainties in when today's UAV systems will "officially" become assets owned, operated, and maintained by the services.

There is funding budgeted by the services for existing airborne ISR platforms in the 2010 force structure projection that has not been adequately identified. The DARP budget has always been a less-than-complete aggregation of the DoD's total funding for all joint-service and defense-wide airborne reconnaissance assets. This gap stems form the differences in service budget database structures and programming procedures that existed (and still exist) when DARO was created. An example is sustainment costs for some systems (e.g., Pioneer) that may not be separately identifiable in service budgets and are therefore not included in the DARO program budget values—even though the costs are included in the DADT life-cycle cost estimate.

The operating concepts and tempo, especially for the emerging UAVs, contribute significantly to the life-cycle cost estimates. The estimate of flying hours (and associated operating hours for the attendant ground and surface systems) for the projected 2010 force mix is more than what is performed today. Even with some expected gains in lowering the cost per operating hour, the future airborne ISR force mix is still projected to have an aggregate annual operating and maintenance cost that is much greater than today's systems. Both of these points are consistent with the migration from an ISR force mix that is capable today of supporting somewhat more than one major theater to the two-major-theater force used for the 2010 projection.

The relatively higher attrition rates (peacetime) projected for UAVs—as compared to manned airborne ISR systems—will place tremendous burdens on managing their operating concepts and tempo to avoid the potentially large annual procurement and operational and maintenance budgets associated with maintaining a "steady state" force structure. From a positive perspective, the annual funding associated with replacing attrition systems would also provide an opportunity for continuous modernization and upgrading of these ISR systems with the latest improvements in technology.

The DADT considered how the "advertised" flyaway price target of $10 million per unit required for the Global Hawk and DarkStar UAVs in production potentially bounds the capabilities of these two platforms. It remains a challenge to develop credible life-cycle cost estimates for potential operational versions of these systems in advance of the formal determination of warfighter requirements. If requirements for UAV capabilities, when determined, result in a Global Hawk UAV system with a substantially higher vehicle flyaway price (e.g., $25 to $35 million), then a decision would have to be made whether to fund several years of modification and development efforts needed to yield an operational "Global Hawk II." DoD's concept of cost as an independent variable will force the acquisition and operational communities to grapple with these issues. Another uncertainty was anticipating the operating concept and tempo of the Global Hawk and DarkStar UAVs. The only available data are "guess-estimates" by the acquisition community—which may or may not reflect how the user community would actually employ these systems in operations. The answers to these and other issues from introducing high altitude and endurance UAVs into the force structure will have significant impacts on the life-cycle cost estimates for UAVs.

Obtaining the best available and most representative cost, technical, and programmatic data for all of the ISR systems included in the study was imperative for developing relevant cost relationships. In particular, life-cycle cost data is typically proprietary or government sensitive, which also includes restricting access to actual data due to political or programmatic considerations by the organizations potentially affected. The airborne ISR community desperately needs a centralized, validated, accessible databank of representative cost, technical, and programmatic data. DARO could be the "honest broker" of such data for use in the various ISR cost and performance trade studies now proliferating throughout the DoD and intelligence communities. Another objective was to identify all of the cost elements that must be estimated in order to derive a complete life-cycle cost estimate for each ISR system. The DARO has a strong interest in developing and fielding airborne ISR systems that meet certain life-cycle cost and performance

goals. To accomplish this, the DARO will want to ensure that accurate data across all system life-cycle phases are available and are used in any study that compares cost with performance.

1.6 THE VIRTUAL PROVING GROUND

The discussions in Section 3 acknowledge the traditional approach to migration, which focuses on analysis and modifications of current and planned programs. The DADT was challenged to provide an alternative view of system migration that, while supporting the traditional approach, responds to both reforms in acquisition and the accelerating pace of innovations in information technology. Section 6 responds to this challenge with a virtual proving ground approach to systems migration. The approach is explained along with descriptions of candidate proof-of-concept experiments for the virtual proving ground. This approach accommodates the explosive changes in information technology, which call for extraordinarily short acquisition and integration cycles, as well as processes for managing uncertainty in the migration decisions.

A traditional top-down development and acquisition approach is not conducive to achieving the vision architecture. The scope of the proposed "cybertecture" spans all of DoD, permeates the domains of warfighters and the intelligence community, and extends into commercial entities for some services. This makes the global ISR enterprise extraordinarily complex in its design. Thus, the relatively simple overall operating concept of the enterprise is hard to define in detail. The fact that much of the cybertecture is not part of the DARO program compounds these problems, making it necessary to continually track migration (or state-of-the-practice) of non-DARO systems to ensure that all parts "plug in" to the overall global enterprise seamlessly and optimally.

Rather than dealing with the vision architecture purely in the abstract (e.g., as a series of specifications and other documents), the DADT proposes that it be further defined and developed through a combination of real-world implementations and virtual-world simulations. This approach is the essence of the virtual proving ground. Various combinations of real and virtual (simulated) instantiations of cybertecture capabilities can approach functionality envisioned for an objective enterprise (see Figure 1-12). Participants in the cybertecture — including users, developers, suppliers, and decision makers — can incorporate, test, and field new ideas and capabilities very rapidly and very efficiently. More importantly, the virtual proving ground approach to migration allows these participants to bring forth a truly integrated ISR enterprise, one that operates as a single complex system rather than a continuing coordination of numerous, individual programs.

The virtual proving ground (VPG) can readily be "constructed" by interconnecting existing laboratory and test-bed facilities through existing communications networks (see Figure 1-13). The key task for DARO is to establish a "presence" on the appropriate networks and coordinate activities of various laboratories to participate in cooperative and integrated ISR experiments and demonstrations. Entities connected together through the networks to configure the virtual proving ground should be structured to reflect entities defined in the vision architecture. At its highest level of abstraction, these entities are consumers, providers, value-added resellers, brokers, and regulators (see earlier discussion). Warfighters' systems would be "brought in" to the virtual proving ground as required for any given experiment or demonstration to represent consumers. Similarly, airborne reconnaissance collection systems or their respective simulators would be tied in as required to represent "providers" in a given experiment or demonstration. Brokers and regulators would be represented in the virtual proving ground operations center, where most of the functionality required to configure and manage the virtual domains would reside.

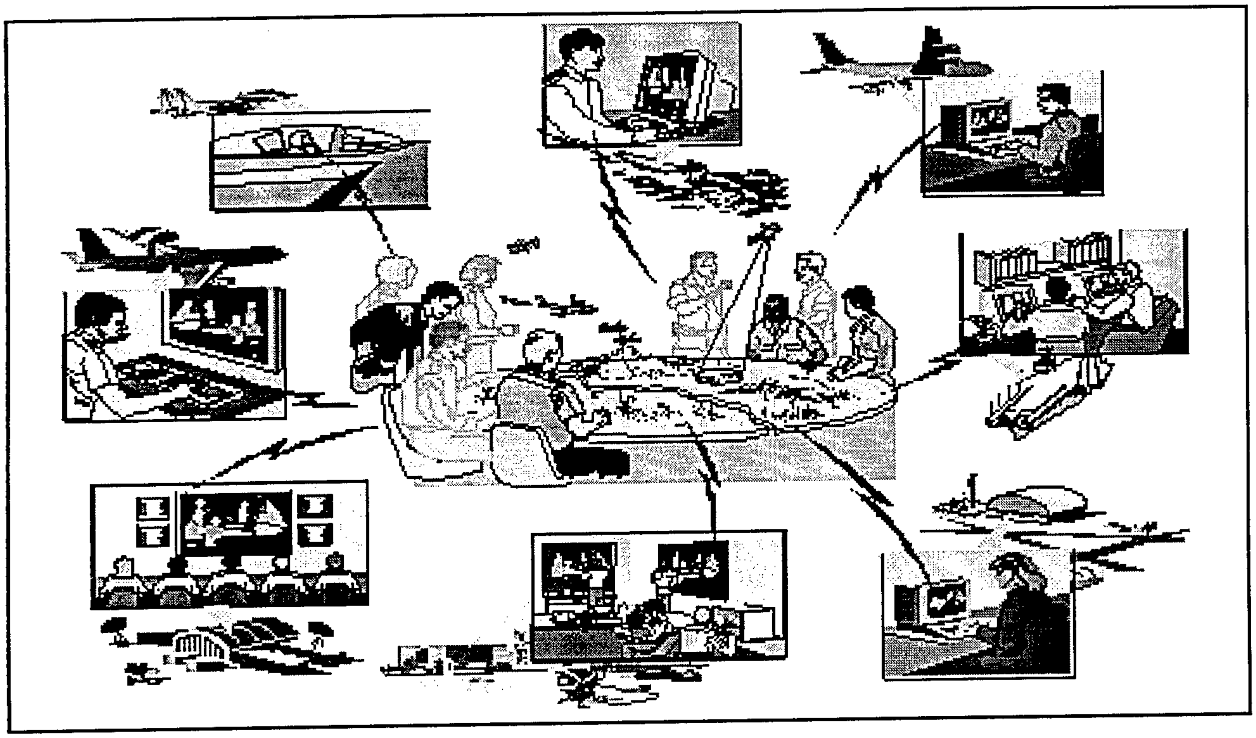

Figure 1-12. Both Real-World and Virtual-World Capabilities Can Be Used in the Virtual Proving Ground

Commensurate with the market-driven enterprise approach articulated for the vision architecture, the virtual proving ground must provide an easy way for nontraditional players to participate in the global ISR enterprise with low cost of entry. This can be done by making connections through the public internet. The DoD and intelligence communities need to solve the security problems associated with letting enterprise entities "live" in an unclassified portion of the ISR cybertecture yet participate on appropriate occasions with government and coalition entities that operate in classified domains. Once solved, this approach will undoubtedly have a much lower cost than the customary approach, in which DoD bears the costs involved with moving these entities into the classified environment each time their specialties are needed.

As the vision architecture was developed, it became possible to identify several specific experiments and demonstrations that could be conducted in the virtual proving ground. These candidate activities offer a way to get the empirical data that DoD will undoubtedly need to make initial, near-term migration decisions. These data are required to calibrate detailed modeling

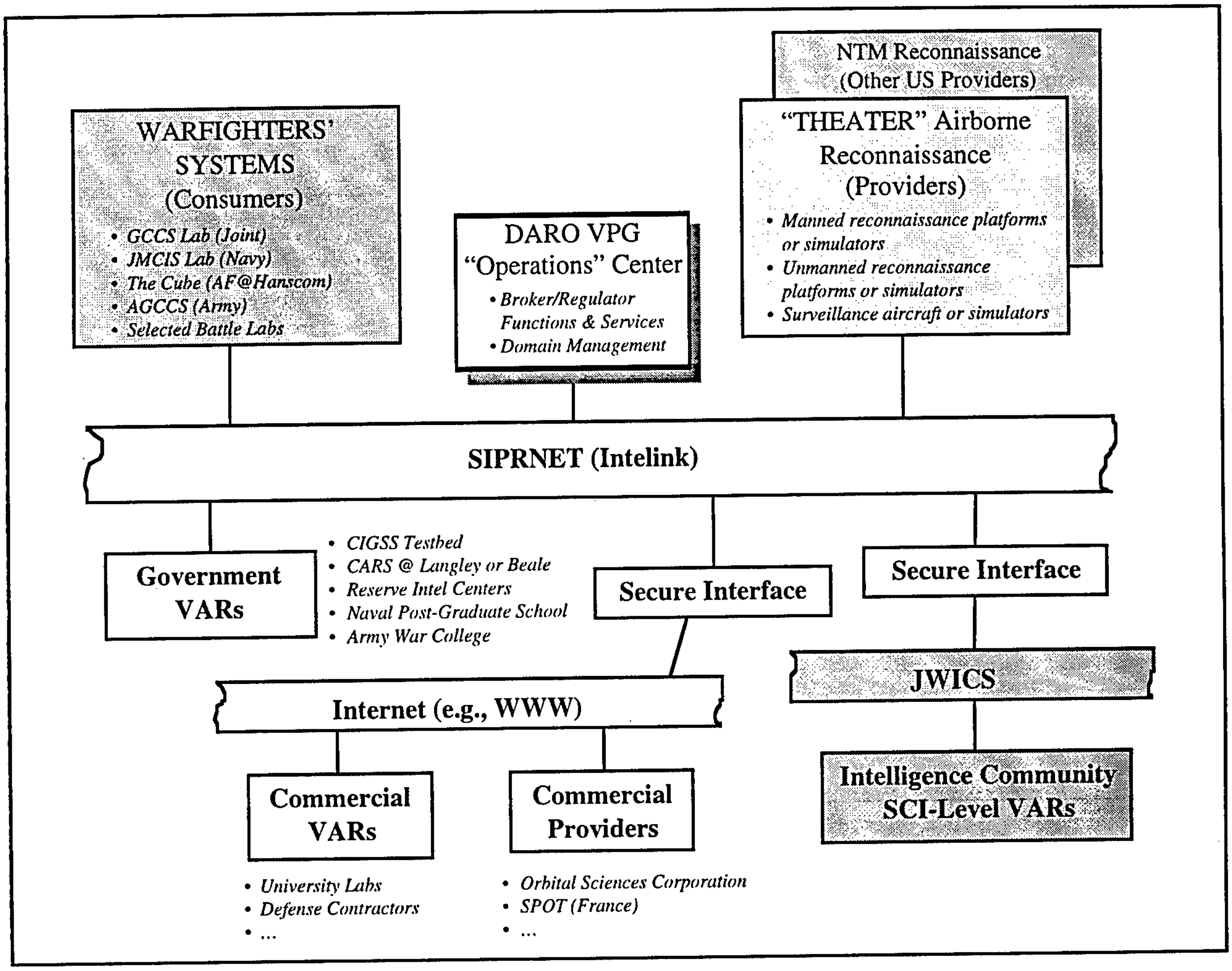

Figure 1-13. The Virtual Proving Ground Can Largely Be Built-Up by Fostering Agreements Among Participants

simulation, and analysis results and to substantiate complex trades performed in support of the decisionmaking process. The details presented in Section 6 include the following candidates for testing in the virtual proving ground.

- ***Network-Centric ISR Concept Development Experiments***. This collection of experiments is aimed at exploring how exemplar ISR products and services could be delivered to warfighters in a network-centric enterprise. The focus is on overall concept development, but experiments also address near-term design, cost, and schedule trades associated with making migration decisions.

- *Moving Target Indicator Concept Demonstration*. This demonstration focuses specifically on advanced concepts for using moving target indication as a primary means for tracking objects in a battle area. If successful, such concepts could fundamentally shift reconnaissance emphasis away from customary methods for certain classes of ISR problems.
- *Dynamic Tasking Concepts* – This area explores new concepts for dynamically tasking (and retasking) airborne reconnaissance assets and delivering real-time ISR products and services. These concepts and demonstrations help shift the sense of user's "ownership" and control from specific systems to the information produced by them.
- *Collaborative Planning Experiment* – This experiment focuses on blending various planning processes to show how automated, concurrent functions (rather than sequential actions) can improve responsiveness of ISR systems to high tempo warfighter operations. These concepts may ultimately eliminate distinctions between the planning processes for operations and intelligence gathering.

One of the greatest benefits from virtual proving ground activities — and a major challenge in planning them — is the ability to sort through the plethora of applicable technological opportunities and innovative concepts and explore them in the context of the vision architecture. A quick scan of worldwide web sites on the Internet shows numerous examples of relevant DoD initiatives in progress. If the independent research and development projects underway in defense contractor laboratories, universities, and commercial companies are added, the list multiplies. The challenge is to sort through all these possibilities and bring the most fruitful to bear on the vision architecture.

DARO is not alone in facing this challenge. The virtual proving ground approach serves to foster unprecedented collaboration in furthering development of an overall, integrated global ISR enterprise capable of delivering the ISR products and services that American warfighters and their coalition partners will require in the 21st century. The warfighters' system-of-systems is far too complex to comprehend and assess in purely abstract, analytical terms; warfighting concepts for future military operations are not mature enough to risk "etching them in stone" today; and information technology is changing much faster than conventional acquisition processes can possibly handle. The virtual proving ground approach to migration overcomes these roadblocks and places the warfighters firmly at the forefront, with DARO support, in leading the way to a fully integrated, network-centric ISR enterprise. The key challenge facing the DoD now is committing the resources to the virtual proving ground as a priority DARO project and making the investment needed to implement the virtual proving ground approach.

1.7 SIGNIFICANT CONTRIBUTIONS

The DADT has made several significant contributions to enhancing the understanding of the complex issues and challenges presented by the DARO's charter responsibility to "develop and maintain the DoD integrated airborne reconnaissance architecture." Contributions documented in this report include the following:

- A visionary context and framework for designing ISR airborne architectures responsive to the revolutionary visions for future military operations — the result being a network-centric, global ISR enterprise that can serve intelligence producers, warfighters, and shooters and that will dominate future battlefields.

- Requirements-based analytical development of an airborne reconnaissance mix of platforms, sensors, and ground and surface stations to satisfy military needs in the 2010 timeframe consistent with the National Military Strategy for supporting two major theaters of war.
- Selection and application of modeling and simulation tools that probe the full spectrum of analysis requirements, including estimation of the percent of requirements satisfied versus life-cycle costs; evaluation of architecture functional flows; assessment of the military worth of various force mixes; analysis of processing, exploitation, and dissemination systems; generation of optimum airborne routes and tracks; trades among different combinations of airborne and overhead performance; and estimates of acquisition costs versus area and point coverage.
- A comprehensive, integrated, and documented set of sensor and platform parameters specifically assembled and verified to support consistent modeling, simulation, and cost estimation across a variety of community-wide ISR studies.
- Complete annualized life-cycle cost analysis of a projected force mix.
- The formation of relationships between DARO and other organizations for joint participation in major ISR studies. Also, the formation of a world-class Technology Advisory Panel to identify technology opportunities that enable future architectures and new concepts of operation.

TABLE OF CONTENTS OVERVIEW

This overview of the Table of Contents of the complete report of the *DARO Airborne Reconnaissance Architecture, Version 0.8, February 1998* is provided for information. The overall classification of the full report is SECRET - U.S. ONLY.

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